

# 2007 Solar Decathlon Rules and Regulations

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## Overview

*The Engineer's aesthetic, and Architecture, are two things that march together and follow one from the other.... The Engineer, inspired by the law of economy and governed by mathematical calculation, puts us in accord with universal law. He achieves harmony. The Architect, by his arrangement of forms, realizes an order, which is a pure creation of his spirit...it is then that we experience the sense of beauty. —Le Corbusier*

The Solar Decathlon is an intercollegiate and interdisciplinary design and construction competition that takes up a persistent and age-old question: How do we integrate architecture and technology with a dwelling? In other words, what makes a good house?

More than 2,000 years ago, the Roman architect Vitruvius claimed that all buildings should possess the qualities of “firmness, commodity, and delight.” Centuries later, architects and engineers of the Industrial Revolution were inspired and challenged by the new technologies and building tasks their age presented. In the early twentieth century, the influential Swiss Modernist architect, Le Corbusier, wrote in *Towards a New Architecture*, “Let us state the problem. Let us shut our eyes to what exists. A house: a shelter against heat, cold, rain, thieves, and the inquisitive. A receptacle for light and sun. A certain number of cells appropriate to cooking, work, and personal life.”

The sources of energy that powered the Industrial Age have revealed their limitations and their consequences, as contemporary living demands more and more energy for “commodity and delight” as well as “cooking, work, and personal life.” Architecture and engineering students of today, then, face both an old and a new problem: to satisfy an age-old curiosity about dwelling while solving the relatively new problem of post-industrial energy and its consequences. The Solar Decathlon challenges engineering and architecture students to design and construct a fully self-sufficient solar-powered house. Or, to paraphrase and gather inspiration from Le Corbusier’s words: a sun-machine in which to live.

Like the athletic decathlon, the Solar Decathlon will test proficiency in a wide range of skills. Unlike its athletic counterpart, however, the Solar Decathlon is a team event, in which the diversity of abilities comes from the composition of the team rather than a single individual. Architecture and engineering students will work with students from other disciplines such as marketing, communications, graphic design, analysis, and computer science to do the troubleshooting, communicating, dreaming, and building this challenging project requires.

The third Solar Decathlon will take place on the National Mall in Washington, D.C., in the fall of 2007. For approximately 3 weeks, the Solar Decathlon organizers and teams will assemble and inhabit a “Solar Village” in view of the Nation’s capitol. When the village is fully assembled, teams will compete against each other during a week of 10 decathlon contests. The team with the highest point total at the end of the week will be the winner. Additional awards will be presented in several other categories. The village also will be open to the public and media, who will be invited to tour the teams’ homes and the educational exhibits provided by the organizers and sponsors.

The 10 contests are based on three guiding principles for the Competition:

- The teams must supply the energy requirements necessary to live and work using only the sunlight shining on their entry—the global solar radiation incident on the house, specifically—during the contests.
- The houses will exemplify good design principles that will increase the public’s awareness of the aesthetic and energy benefits of solar and energy efficiency design strategies and technologies, which in turn will increase the use of these design principles and technologies.
- The work of the teams, organizers, and sponsors will stimulate accelerated research and development of renewable energy, particularly in the area of building applications.

The following set of priorities determines what the 10 contests should encompass.

- ***Energy Production:*** Each team’s house must be able to supply all of the energy needed for its occupants to survive and prosper in today’s society. Within their comfortable and well-lit houses, the teams will perform domestic tasks that require the operation of appliances and electronics, and they will transport themselves around town in an electric vehicle—all of this with energy from only the solar electric and solar thermal systems integrated into their houses. The Competition will quantify each team’s energy production and productive output.
- ***Energy Efficiency:*** Efficiency reduces consumption and enables more work to be accomplished with a given amount of energy. Because the amount of sunlight that strikes the surface of a house is limited, end-use efficiency will be a key strategy to success.
- ***Design:*** Since the time of Vitruvius, design has been an essential part of deciding what makes “a good house.” Good design improves structural integrity (“firmness”), function and comfort (“commodity”), and aesthetic appeal (“delight”). Whether a house is a “good house” may be qualified by the architect who designs it, the engineer who optimizes its performance, the builder who constructs it, and the occupant who lives and works in it. Good design becomes more challenging as the building industry strives to integrate existing ideas and technologies with an increasing array of new ideas and technologies, many of which are just being introduced. Design is a critical part of the Solar Decathlon, emphasizing overall dwelling livability and structural and systems aesthetics and integration, especially integration of the dwelling with its energy systems.
- ***Project Documentation:*** Good design is as much a process as it is the result evidenced in the finished house. The Competition requires teams to demonstrate their design processes by providing documentation such as energy performance analyses, drawings, and design narratives at various phases of their projects.

- ***Communications:*** Effective communications save time and improve our safety and quality of life by supplying the important information we use to make critical decisions. Variety, content, and design are essential to drawing an audience to a message. Getting a clear message about delightful design, energy efficiency, and solar energy to the public audience will be an important consideration in this Competition.
- ***Heating and Air Conditioning:*** As Le Corbusier stated, a house must be a comfortable space in which to live, protected from wind and rain, from winter's snow, and summer's heat. For good health, the conditioned space must also minimize indoor pollutants. To succeed, the teams' houses must provide interior comfort and good environmental quality while meeting the energy requirements of the Competition.
- ***Appliances and Electronics:*** Household appliances and electronics have improved our quality of life since the dawning of the industrial age. They use energy to save the physical energy and time of a household's inhabitants, and they provide entertainment and access to global communications. The demand for appliances and electronics grows greater every day, even as the consequences of supplying the energy they require becomes ever more apparent. The Solar Decathlon will challenge students to meet the energy demands of domestic and working life while competing to solve the problem of the consequences of energy use in the post-industrial age.
- ***Hot Water:*** Hot running water is considered a necessity. Energy- and water-saving strategies and technologies are readily available. The Competition challenges the teams to demonstrate these options while meeting average hot water requirements for domestic activities.
- ***Lighting:*** Lighting improves our safety, productivity, and quality of life. Beyond its purely practical application, lighting also has the power to please the inhabitants of the "receptacle for light" that Le Corbusier described. The Solar Decathlon requires teams to design lighting solutions that are energy-efficient and abundant, as well as pleasing to the houses' inhabitants.
- ***Transportation:*** Mechanized transportation gives us greater freedom, saves time, and improves productivity. The Competition will reward teams that can plan their use of transportation the most efficiently and that use their houses' energy systems to provide the energy to meet their transportation needs.

## Team Selection

The Solar Decathlon is an international Competition open to all accredited colleges, universities, and other post-secondary educational institutions. Entrants are selected through a proposal process. All proposals are reviewed, scored, and ranked. Depending on the quantity and quality of submissions, a limited number of teams from all entries are selected.

For the 2007 Solar Decathlon, the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) issued a Request for Proposals in October 2005. Proposals were due in December 2005. After reviewing, scoring, and ranking the proposals, a team of reviewers from DOE and NREL selected the following teams to compete in 2007:

- California Polytechnic State University, San Luis Obispo, California
- Carnegie Mellon University, Pittsburgh, Pennsylvania
- Cornell University, Ithaca, New York
- Georgia Institute of Technology, Atlanta, Georgia
- Kansas State University, Manhattan, Kansas
- Lawrence Technological University, Southfield, Michigan
- Massachusetts Institute of Technology, Cambridge, Massachusetts
- New York Institute of Technology, Old Westbury, New York
- Team Montreal (École de Technologie Supérieure, Université de Montréal, McGill University), Montreal, Canada
- Technische Universität Darmstadt, Darmstadt, Germany
- Texas A&M University, College Station, Texas
- The Pennsylvania State University, University Park, Pennsylvania
- Universidad de Puerto Rico, Río Piedras and Mayagüez, Puerto Rico
- Universidad Politécnica de Madrid, Madrid, Spain
- University of Cincinnati, Cincinnati, Ohio
- University of Colorado, Boulder, Colorado
- University of Illinois at Urbana-Champaign, Urbana, Illinois
- University of Maryland, College Park, Maryland
- University of Missouri-Rolla, Rolla, Missouri
- University of Texas at Austin, Austin, Texas

## The 10 Contests

The Solar Decathlon organizers have selected the following 10 contests for the 2007 Competition. The teams can earn up to 100 points for each contest except Architecture, for which they can earn up to 200 points and Engineering and Market Viability, for which they can earn up to 150 points. Of the 1200 total points possible, 525 points are awarded based on objective performance measurements or task completion, and 675 points are awarded through subjective evaluations by a variety of appropriately selected experts. For details about scoring: [The Contests](#).

### ***Contest 1: Architecture***

To be architecturally sound, a home's design must not only satisfy human comfort needs, it must also be well organized and visually pleasing both inside and out. The Architecture contest is intended to demonstrate that solar-powered, energy-efficient homes can be designed to meet enduring architectural standards. A jury of architects will judge each entry on the overall aesthetics and the successful design and integration of the solar, energy-efficiency, and other technical features of the house. The jury will evaluate the houses early in the week of contests and will not be influenced by the objectively measured performances of the houses. For more details see [Contest 1: Architecture](#).

### ***Contest 2: Engineering***

Although architects are critical collaborators in the engineering design of well-integrated high performance homes, engineers and other technical experts possess unique skills that are required to design, specify, install, and maintain the house's systems. A jury of technical experts in the residential building industry will judge each entry on the functionality, efficiency, innovation, robustness, and economic value of the house's building envelope, environmental control, mechanical, electrical, and plumbing systems. For more details see [Contest 2: Engineering](#).

### ***Contest 3: Market Viability***

An important objective of the Solar Decathlon is to prove that homes containing solar and energy-efficient design and technologies are market ready and belong in the world's diverse neighborhoods. Experts from the building industry will compose the jury for this contest. Judging will take place early in the week of contests and will not be influenced by the objectively measured technical performance of the houses. For more details see [Contest 3: Marketability](#).

### ***Contest 4: Communications***

The Solar Decathlon is a competition and a public event. The Communications contest challenges teams to communicate their experiences in this project to a general audience. Through Web sites and public tours, the teams will share the knowledge they have acquired. Their experiences and their houses will serve as living demonstrations of the viability of solar energy and energy efficiency technologies in the home. Panels of judges with expertise in communications and public relations will award points based on subjective evaluations of the teams' Web sites and house tours. For more details see [Contest 4: Communications](#).

### ***Contest 5: Comfort Zone***

Well-designed houses provide a safe and comfortable indoor environment for occupants through heating, cooling, humidity, and ventilation controls. In this contest, the teams will be evaluated objectively on their ability to maintain temperature and relative humidity within prescribed set points. Other aspects of indoor environmental quality will be evaluated in Contest 2: Engineering. For more details see [Contest 5: Comfort Zone](#).

### ***Contest 6: Appliances***

A house is not a home without kitchen appliances, laundry facilities, and electronics such as personal computers and TV/video players. This contest requires the teams to demonstrate that their houses can provide the necessary energy to effectively operate appliances and electronics. The teams will store food in their refrigerators and freezers, host a dinner party, wash dishes, and do laundry during the week of contests. The teams will also be required to operate their personal computers and TV/video players a set number of hours each day. All points for this contest will be awarded based on task completion and objective performance evaluations of the required appliances and electronics. For more details see [Contest 6: Appliances](#).

### ***Contest 7: Hot Water***

This contest demonstrates that the teams' houses can provide all of the energy necessary to heat water for domestic uses. Teams will receive points for performing tests that simulate the average time and temperature requirements for two showers each day of the contest week. Twice per day, teams will have to deliver 15 gallons (56.8 liters) of hot water (at least 110°F [43.3°C]) in no more than 10 minutes. For more details see [Contest 7: Hot Water](#).



### ***Contest 8: Lighting***

Sunlight, moonlight, and electric light all contribute to the livability and environment of a dwelling, inside and out. Lighting systems should be designed to minimize energy use by maximizing the contribution of daylighting and by using controls to minimize the use of electric illumination. This contest evaluates the quantity and quality of the lighting in the houses both day and night. Points will be awarded on a team's ability to provide acceptable lighting levels for specified durations. A jury of lighting experts will award points on the basis of subjective evaluations of the teams' lighting system designs. For more details see [Contest 8: Lighting](#).

### ***Contest 9: Energy Balance***

This contest demonstrates that the sun can supply the energy necessary for all the daily energy demands of a small household. The object is to produce as much or more energy than the house consumes over a defined period of time to demonstrate that the house and its systems function sustainably. Points will be awarded based on each team's ability to use their solar electric systems to produce as much electrical energy as they require during the contest week. For more details see [Contest 9: Energy Balance](#).

### ***Contest 10: Getting Around***

Because the amount of energy households use to meet their personal transportation needs is so significant, this contest is designed to demonstrate that a house itself can be used to provide that energy. The contest evaluates how much "extra" energy the houses can generate to provide transportation for the teams in street-legal, commercially available electric vehicles, which will be provided by the organizers. All points for this contest will be awarded based on objective evaluation—the more miles the teams drive, the more points they get. For more details see [Contest 10: Getting Around](#).

## Definitions

*Assembly*—Activities of the Teams and Organizers that have to do with assembling and installing the Solar Decathlon Solar Village on the National Mall for the Event and Competition.

*Chief Observer*—The individual selected by the Organizers to direct and oversee the activities of the Observers.

*Competition*— All aspects of the Solar Decathlon that relate to the 10 Contests and the scoring of those Contests.

*Construction*—The Teams' activities that have to do with constructing their Solar Decathlon houses (all of the components) on the teams' original sites (e.g., their campuses) before the houses are transported to the National Mall for the Event and Competition.

*Contest*—One of the 10 categories in which teams will be evaluated against each other to determine a winner of the Competition.

*Contest Activity*—An individually scored component within a Contest. Some Contests consist of only one Contest Activity; other Contests consist of multiple Contest Activities.

*Contest Officials*—Individuals appointed by the Organizers to monitor specific Contest Activities. Contest Officials are responsible (1) for interpreting the Rules and Regulations specific to the Contest(s) that they have been appointed to officiate and (2) for identifying any infractions of the Rules and Regulations that relate to those Contest(s).

*Contest Week*—The period of approximately 7 to 9 days on the National Mall when some or all Contests are active.

*Decathlete*—A registered, student team member allowed to participate in Contest Activities during the Contest Week.

*Director*—The individual with the ultimate decision-making authority regarding all aspects of the Project.

*Disassembly*—Activities of the Teams and Organizers that have to do with the expeditious removal of everything (e.g., structures, equipment, tools, vehicles, trash, and debris) from the National Mall after completion of the Event and Competition.

*Event*—The series of activities that take place at the Event site (in Washington, D.C., and on the National Mall). Activities include, but are not limited to, registration, Assembly, inspection, Competition, special events, hours of public access, and Disassembly.

*Event Sponsor*—An entity identified by the Organizers that supports the overall Solar Decathlon. The U.S. Department of Energy (DOE) is the primary sponsor of the Solar Decathlon. DOE partners with other institutions—such as its National Renewable Energy Laboratory (NREL), the American Institute of Architects, and BP—support the Project.

*Event Staff*—A team of individuals selected by the Organizers to conduct Event activities that include, but are not limited to, registration; safety; village infrastructure, logistics, and Assembly; inspections; instrumentation and monitoring; special events; communications and public outreach; media relations; Contest evaluations; and Disassembly.

*Faculty Advisor*—An individual team member who is a faculty member from one of the institutions (i.e., school, college, or university) selected for participation in the Project. The Faculty Advisor provides guidance to the team on an as-needed basis throughout the Project and obtains appropriate signatures on documents that require the institution's or institutions' concurrence or authorization.

*Headquarters*—During the Event, a Headquarters established at the Event site houses administrative and management functions for the Event.

*Inspectors*—The individuals selected by the Organizers to conduct inspections to ensure compliance with Solar Decathlon Rules and Regulations, including the Solar Decathlon Building Code.

*Juror*—Individual selected by the Organizers to serve on a Jury.

*Jury*—A group of individuals selected by the Organizers to carry out Contest Activities requiring subjective evaluations.

*Observer*—A person who is assigned to a team or teams by the Chief Observer to observe team activities during the Competition. The Observer reports to the Chief Observer any observed violation of the Rules and Regulations but does not provide an official interpretation of the Rules and Regulations. The Observer also verifies that tasks are completed.

*Official Scores*—The final scores provided by the Scoring Official at the end of the Competition.

*Organizers*—The body of individuals selected by the Director and Project Manager to be responsible for organizing the Project. The Organizers select Contest Officials, the Scoring Official, the Scorekeeper, Inspectors, Jurors, Observers, the Rules and Regulations Committee, the Protest Resolution Committee, and Event Staff.

*Project*—All activities involved in the Solar Decathlon from the initial meetings through the conclusion of the Event.

*Project Manager*—The individual who manages all aspects of the Project, including (but not limited to) such personnel as the Organizers, Rules and Regulations Committee, Inspectors, Jurors, and Event Staff.

*Protest Resolution Committee*—The group of individuals selected by the Organizers to resolve appropriate team protests during the Competition.

*Protest Resolution Committee Chair*—The individual selected by the Organizers to oversee the activities of the Protest Resolution Committee.

*Rules and Regulations*—This document and any requirements, procedures, permissions, and guidelines that govern the Solar Decathlon Project.

*Rules and Regulations Committee*—The group of individuals selected by the Organizers to be responsible for writing and revising this Rules and Regulations document and its amendments. The Rules and Regulations Committee is also responsible for writing or providing (or both) supplemental documents to the Rules and Regulations.

*Rules and Regulations Committee Chair*—The individual selected by the Organizers to be responsible for overseeing the activities of the Rules and Regulations Committee.

*Solar-Only Period*—The period of time between 10:00 a.m. on the 5<sup>th</sup> day of the Event and the conclusion of public tour hours on the final public tour day, during which the use of nonsolar fuels is allowed with explicit Organizer approval, but not without a severe penalty.

*Scorekeeper*—The individual selected by the organizers to operate and maintain the Scoring Spreadsheet during the competition.

*Scoring Official*—The individual selected by the Organizers to be responsible for unofficial and official scores.

*Scoring Spreadsheet*—This detailed computer spreadsheet collects and displays data from each team's remote datalogger and provides a place to record data that are not available from remote dataloggers. Unofficial and Official scores are calculated within the spreadsheet.

*Team Member*—An individual student, faculty member, or other employee from one of the institutions (i.e., school, college, or university) selected to participate in the Project.

*Team Sponsor*—An entity identified by a team that supports the team's participation in the Solar Decathlon.

*Unofficial Scores*—All scores published before Official Scores are published.

# Competition Regulations

## 1. Administration

### *1.1 Rules and Regulations Authority*

The Solar Decathlon Rules and Regulations are issued under the authority of the Rules and Regulations Committee. Official printed or electronic communications from the Rules and Regulations Committee and/or Organizers shall be considered part of, and shall have the same validity as these Rules and Regulations. If there is a conflict between official printed or electronic communications and these Rules and Regulations, the information having the later date shall take precedence. Official communications will be made available to the teams via one or more of the venues indicated in Regulation 2: Official Communications.

If there is any doubt or ambiguity as to the wording or intent of these Rules and Regulations, the decision of the Rules and Regulations Committee shall prevail. Infractions of these rules can lead to warnings, point penalties and, in extreme cases, disqualification. Safety and good sportsmanship will not be compromised.

### *1.2 Effective Date of Rules and Regulations*

The Rules and Regulations posted on the Solar Decathlon Web site and dated for the year of the Event are the Rules and Regulations in effect. Rules and Regulations dated for other years are invalid.

### *1.3 Violations of Intent*

A violation of the intent of a rule or regulation will be considered a violation of the rule or regulation itself. Questions about the intent of a rule or regulation may be addressed to the Rules and Regulations Committee per the instructions in Regulation 2: Official Communications.

### *1.4 Rules and Regulations Compliance*

By entering a Solar Decathlon Project, the team, faculty advisor, and the members of the team as individuals agree to comply with, and be bound by, these Rules and Regulations and any procedures announced by the Organizers.

## 1.5 Organizer Authority

The Organizers of the competition reserve the exclusive right to revise the schedule of the Project and to interpret or modify (or both) the Rules and Regulations at any time and in any manner that is, in their sole judgment, required for the efficient operation or safety of the competition.

## 2. Official Communications

It is the teams' responsibility to stay current with official communications regarding the Project. Official communication between the teams and the Director, Project Manager, Organizers, Rules and Regulations Committee and Chair, Headquarters, Inspectors, Event Staff, Contest Officials, Chief Observer, Scoring Official, Protest Resolution Committee Chair, and any other Solar Decathlon staff and officials will occur through, but not be limited to, one or all of the following. (Teams will be notified of any changes in methods or venues for official communications.)

- *Solar Decathlon Yahoo! Group also known as "the Group"*: All official communication suitable for viewing by all teams will be posted on the Yahoo! Group (open to teams and Organizers only) (<http://groups.yahoo.com/group/SD2007/>). The Group includes a section for posting files. If files are too large, they will be posted on the Solar Decathlon ftp site or Web site, and the teams will be notified via the Group as to where they can locate the files. The Group Calendar indicates deadlines for project deliverables. Teams must follow the Organizers' instructions (provided to each team in January 2006) to join the Group. The Group will be the primary venue for official communications, so the teams should check the Group often for new information.
- *Rules and Regulations Committee Chair Email*: For confidential inquiries regarding the Project, teams should email the Rules and Regulations Committee Chair ([sdrules@nrel.gov](mailto:sdrules@nrel.gov)). The Chair will route these inquiries appropriately, and the inquiries will be kept confidential.
- *Solar Decathlon ftp site*: The ftp site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/](ftp://ftp.nrel.gov/pub/solar_decathlon/)) will be used by the Organizers to make large files available to the teams. The Organizers may also request that the teams use the ftp site to make large files available to the Organizers. Notification of or requests for file transfers will be made via the Yahoo! Group or email.
- *Solar Decathlon Web site*: Space on the Yahoo! Group is limited. Files of a more permanent nature (e.g., the official Rules and Regulations) will be made available via the Solar Decathlon Web site (<http://www.solardecathlon.org/>). Notification of new or updated information on the Web site will be provided via the Group.
- *Conference calls*: The teams will be required to participate in periodic informational sessions via conference calls. Invitations and instructions for participation in conference calls will be provided via the Group.
- *Meetings*: Before the Event, the teams and Organizers will likely have an in-person meeting in early 2007. During the Event, a meeting will be held the day before assembly begins on the Mall, and meetings will be held daily on the Mall throughout the Event.

- *Postings at Headquarters:* During the Event, a bulletin board (or other obvious venue for posting information) may be established at Headquarters. Teams will be notified via the Group or email if such a venue is established and the purpose for which it has been established.
- *Email:* For expediency and to protect confidentiality, the Organizers may choose to communicate with teams via team members' email addresses provided to the Group. However, the bulk of official communication will occur via the Group and the Web site.

### **3. Communications Materials**

Communications materials refer to all content, graphics, and photographs that appear in any submissions to the Organizers and to any products (print, electronic, video or film, and merchandise) for fund-raising, marketing, advertising, educational, promotional, publicity, team identification, and public outreach purposes.

#### ***3.1 Organizer and Event-Sponsor Use of Likeness, Content, and Images***

By entering the Project, Event, and Competition, all teams, Team Members, contractors, and volunteers agree to the use of their names and their likenesses in any communications materials that may be issued by the Organizers or Event Sponsors. By entering the Project, Event, and Competition, all teams and Team Members agree to the use of any content, graphics, and photos from any communications materials and project deliverables that they produce for the Project in any communications materials produced by the Organizers or Event Sponsors. Content and images (graphics and photos) may be made available to the general public via the U.S. Department of Energy's, the National Renewable Energy Laboratory's, and the Event Sponsors' Web sites with unrestricted use. Images and content, and any publications in which the images and content appear, may be viewable without restrictions on the Internet. Before July 2007, if the teams submit content or images they would like to be kept confidential, they should make that request, with an explanation, in writing to the requestor of the content or images. For example, if a team would like to keep specific content or images in the design development drawings and specifications confidential, they should note that in a cover letter with the submission. Every effort will be made to honor requests for confidentiality. The Organizers and Event Sponsors will make all reasonable efforts to credit the sources of content and images, although they may be published without credit. To ensure proper usage of and credit for images, teams should submit photos and graphics by following the [Instructions for Submitting Images](#).

#### ***3.2 Event-Sponsor Recognition***

All communications materials produced by the teams or Team Sponsors concerning or referring to the Project will refer prominently to the Project as the Solar Decathlon. All communications materials produced by the teams will credit the U.S. Department of Energy, the National Renewable Energy Laboratory, and additional Event Sponsors as indicated by the Organizers. The Solar Decathlon will be recognized with text and logo wherever other logos are used. Information regarding current Event Sponsors, artwork for the Solar Decathlon, and Event Sponsor logos will be available on the Solar Decathlon Web site (<http://www.solardecathlon.org/>).

### **3.3 Team Uniforms**

The only information or graphics that are approved to be visible from the front of the team uniform (jacket, shirt, hat, or other wearable item) shall be the institution and its logo, the team name and logo, the Solar Decathlon logo and Event Sponsor logos as indicated on the Solar Decathlon Web site (<http://www.solardecathlon.org/>). The institution and its logo, the team name and its logo, the Solar Decathlon logo, and Event Sponsor logos are approved to be visible on either the front OR the back of the team uniform. Team sponsor logos are approved to be visible ONLY on the back of the team uniform. Team sponsor logos shall not be visible on the front of the team uniform.

## **4. Safety/Insurance**

Each team is responsible for the safety of its house, vehicles, and Team Members, and for obtaining all necessary insurance (see [Regulation 8.10](#) for details). Passing inspection or implementing changes suggested by the Director, Project Manager, Organizers, Rules and Regulations Committee, Event Staff or any other person associated with the Solar Decathlon does not release the teams from liability. Team members must behave in a safe manner at all times. All houses, vehicles, equipment, and tools must be maintained and operated safely at all times. Children under the age of 13 are not permitted to be on the teams' sites during Assembly and Disassembly. A team may be disqualified and withdrawn from the Project at any time if they behave or operate their house, vehicles, equipment, or tools in an unsafe manner. Organizers and Event Staff may issue a stop work order at any time during the Project if they perceive any safety violation. The Director or Project Manager (or both) will make the final determination as to the severity of and penalty for (up to disqualification) a safety violation.

Each team's house must be equipped with proper personal protective equipment (PPE) to provide to all of its workers during the Event. At a minimum, teams must provide an adequate amount of hard hats; climbing harnesses; ear plugs; eye protection; work gloves; work boots; chemical-resistant gloves, aprons and eye protection for servicing battery banks; and protection from any other thermal, electrical, mechanical or fluid system that presents any kind of hazard.

## **5. Conduct**

Penalties, including disqualification from the Project, Event, and Competition may be imposed for improper conduct or for the use of alcohol or illegal substances. Improper conduct may include but is not limited to improper language, unsportsmanlike conduct, unsafe behavior, distribution of inappropriate media, or cheating. See Regulation 6, Penalties, about the process for qualifying, quantifying, and assessing penalties and for more information about disqualification.



## **6. Penalties**

Any team failing to comply with these Rules and Regulations during the Project may be penalized. Penalties range from official warnings to point penalties to disqualification from the Project, Event, or Competition. During the Project, it is the Project Manager's responsibility (in consultation with Contest Officials, Event Staff, Jurors, Inspectors, Observers, Organizers, or the Rules and Regulations Committee, depending on the nature of the infraction) to determine whether an infraction has occurred. If an infraction has occurred, the Project Manager shall qualify the severity of the incident and quantify the appropriate penalty. The Project Manager will submit all point penalties to Solar Decathlon Headquarters for posting. The Scoring Official will assess and post all penalties before the announcement of official scores. Disqualification of a team from the Project requires prior notice to the team, an opportunity for the team to make an oral or written statement on its own behalf, and, finally, the concurrence of the Director.

## **7. Protests**

Any team desiring to file a protest must do so by submitting an official written protest to Solar Decathlon Headquarters within the time stipulated in Regulation 7.2, Time Limit. The protest shall include the name and signature of the team leader, the current date and time, an acknowledgement that a filing fee will be assessed (see below), and a succinct description of the protest. Protests may be filed for any reason, including disputing a penalty levied against any team, correcting point errors, or protesting the actions of another team. A "filing fee" of 10 points, which could be refundable, will be assessed against the team's Official Score. The Protest Resolution Committee Chair (in consultation with Contest Officials, Event Staff, Jurors, Inspectors, Observers, Organizers, or the Rules and Regulations Committee, depending on the nature of the protest) will evaluate the appropriateness of all team protests to determine which protests the Protest Resolution Committee should review. The decision will be based on the documentation submitted. No appearance is authorized. No right to counsel is authorized.

### ***7.1 Protest Decisions***

The decision of the Protest Resolution Committee is final, and no further appeals are allowed. The Protest Resolution Committee Chair will notify Solar Decathlon Headquarters of its decision, and Headquarters then will inform the affected teams. Based on its assessment and decision, the Protest Resolution Committee may refund some of or the entire filing fee to the filing team's score.

### ***7.2 Time Limit***

Except for the last day of Contest Week, all protests must be filed within 24 hours of the action being protested. The latest possible time for filing protests is 5 minutes following the conclusion of the final active Contest Activity on the final day of Contest Week.

## **8. Team Requirements**

### **8.1 *Entry***

The Project is open to colleges, universities, and other post-secondary educational institutions. Entry is determined through a proposal process. All proposals will be reviewed, scored, and ranked. Subject to the quantity and quality of submissions, a limited number of teams, out of the total number of institutions that submitted proposals, will be selected for entry.

### **8.2 *Faculty Advisor***

Teams must have at least one Faculty Advisor who will provide guidance on an as-needed basis throughout the Project. The Faculty Advisor will be responsible for obtaining appropriate signatures on documents that require the school's or schools' concurrence or authorization.

### **8.3 *Team Members***

Only post-secondary students (including current students or students who have graduated within 12 months of the Event) and faculty from the institutions selected by the Organizers to participate in the Project can be Team Members. However, teams are encouraged to seek assistance from experts in industry, research, and academia.

### **8.4 *Decathletes***

Only registered Decathletes will be allowed to compete in the 10 Contests and actively participate in Contest Activities. During the Contest Week, a team shall have a maximum of six Decathletes operating the house and two decathletes operating the car at one time. The same eight individuals do not have to remain Decathletes for the entire Contest Week. Decathlete status is transferable to other student Team Members. Teams will be allotted eight Decathlete badges for tracking purposes. In addition to meeting the Decathlete requirements, car drivers and passengers must be 18 years old or older and present a valid driver's license and evidence of insurance. The Faculty Advisor and any other non-student Team Members may not be Decathletes. Faculty Advisors are permitted to participate in an advisory role only. Decathletes and other team members shall have primary decision-making authority concerning matters of strategy, house operation, and other competition-related issues.

## **8.5     *Registration***

All Team Members taking part in the Event must register. On-line registration and onsite (in Washington, D.C., and on the Mall) registration will be available for Team Members. Team Members are encouraged to register on-line, because on-site registration could cause delays in their access to their team's site on the Mall. When they register, Team Members must complete all required information and forms, and provide a photo for a photo ID badge. These badges are required for all access to the entire site on the Mall during certain times and to certain restricted areas. Badges must be visible at all times. Team contractors, volunteers, and visitors must register on site and complete all required information and forms. In some cases, team contractors, volunteers, and visitors may be issued a photo ID badge. Each participant (Team Members, contractors, volunteers, and visitors) must register individually; no group registration will be allowed. Visiting media must check in with Headquarters.

## **8.6     *Uniforms***

During the Competition from 7:00 a.m. to 10:00 p.m., and during special events specified by the Organizers or Event Staff, all Team Members present on the National Mall or the site of a specified special event shall wear uniforms representing their institution(s) (i.e., school, college, or university).

## **8.7     *House Transport, Assembly, and Disassembly***

Teams shall be responsible for the transport of their houses, the houses' contents, electric vehicles, and all equipment and tools necessary for the Event and shall be responsible for any damage to or loss of such items. Teams are responsible for procuring any equipment, tools, and supplies at the Event.

## **8.8     *Travel, Accommodations, and Lodging***

All teams are responsible for their team's transportation, accommodations, lodging, food, and beverages (including drinking water) during the Event. Teams are responsible for making their own reservations and arrangements and for covering all necessary costs.

## **8.9     *Withdrawals***

Any team wishing to withdraw must notify, in writing, the Project Manager (before the Event) or Headquarters (during the Event). All written withdrawals signed by the team leader are final. The Project Manager or Headquarters may disqualify teams that do not meet Project requirements or that fail inspections during either the Project or Event. Any disqualification decision shall be in writing and, once presented to the team, the decision shall be final.

### **8.10    *Vehicular and General Liability Insurance***

The school, at the school's expense, shall maintain for the duration of the Event, vehicular liability insurance with limits of liability for bodily injury of not less than US \$200,000.00 for each person and US \$500,000.00 for each occurrence; and limits of liability for property damage of not less than US \$40,000.00 for each accident and US \$500,000.00 for each occurrence. The Released Parties shall be named as Additional Insureds on all such insurance.

The school, at the school's expense, shall maintain for the duration of the Event, general liability insurance with limits of liability for bodily injury of not less than US \$500,000.00 for each person and US \$500,000.00 for each occurrence; and limits of liability for property damage of not less than US \$100,000.00. The Released Parties shall be named as Additional Insureds on all such insurance.

The school, at the school's expense, shall maintain for the duration of the Event, workers' compensation insurance with limits of liability as required by applicable law; and employer's liability insurance for liability for bodily injury of not less than US \$100,000.00 for each person and US \$100,000.00 for each occurrence. To the extent permitted by applicable law, the Released Parties shall be named as Additional Insureds on all such insurance.

The school agrees to furnish NREL, upon acceptance of its proposal, evidence satisfactory to NREL of such vehicular liability, general liability, workers' compensation liability, or employer's liability insurance coverage.

## **9.      Impound**

All houses and cars must be impounded on specified nights during Contest Week from 10 p.m. to 7 a.m. under the direct supervision of official Solar Decathlon personnel. No Team Members are allowed to occupy, move, or conduct maintenance on any part of the house or car during impound hours.

## **10.    Inspections**

All houses will be inspected for compliance with the Solar Decathlon Rules and Regulations. Inspectors will spend most of their time inspecting for compliance with Regulations 11 through 16 in this section and with the [Solar Decathlon Building Code](#), including the [National Park Service Regulations](#).

Each team participating in the Event must present its house for inspection before the Contests to verify compliance. Unless a team is ready for inspections before other teams, the order of inspections will be determined in a drawing. A team that fails to present its house at its designated time will drop to the back of the queue and will risk not having enough time to complete the inspection process. In addition,

spot checks for compliance may take place during and immediately after the Contests. The top five overall finishing houses and cars may be impounded immediately following the Contests for a final Inspection.

After Event inspections, teams will have 24 hours to bring an identified violation into compliance, or the team may be penalized. Teams may not be able to compete in any Contest until inspections have been passed.

## **11. The House and Site**

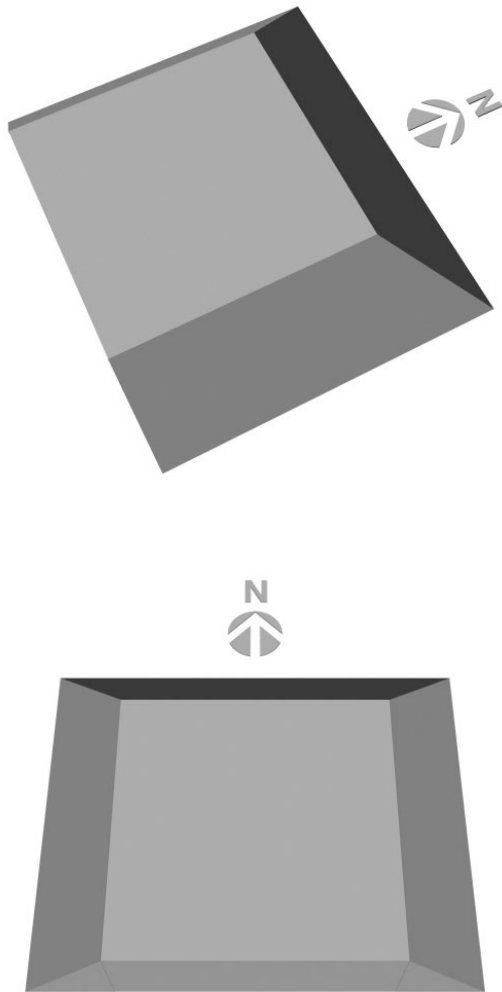
### ***11.1 Team Lots***

Teams will be allowed roughly 5500 ft<sup>2</sup> (511.0 m<sup>2</sup>) of nearly level, unobstructed land and will have approximately 4 days to assemble their houses on the National Mall. Leveling of the floor deck will be necessary (see Section 6.5 in the Solar Decathlon Building Code for more information). There are no limits on materials or type of construction as long as applicable codes are followed. The house can either be transported to the site already assembled or transported and assembled on site, as long as it does not damage the site. The lot size will be 82 ft (25.0 m) east to west by 67 ft (20.4 m) north to south. Please refer to Figures 1 and 2.

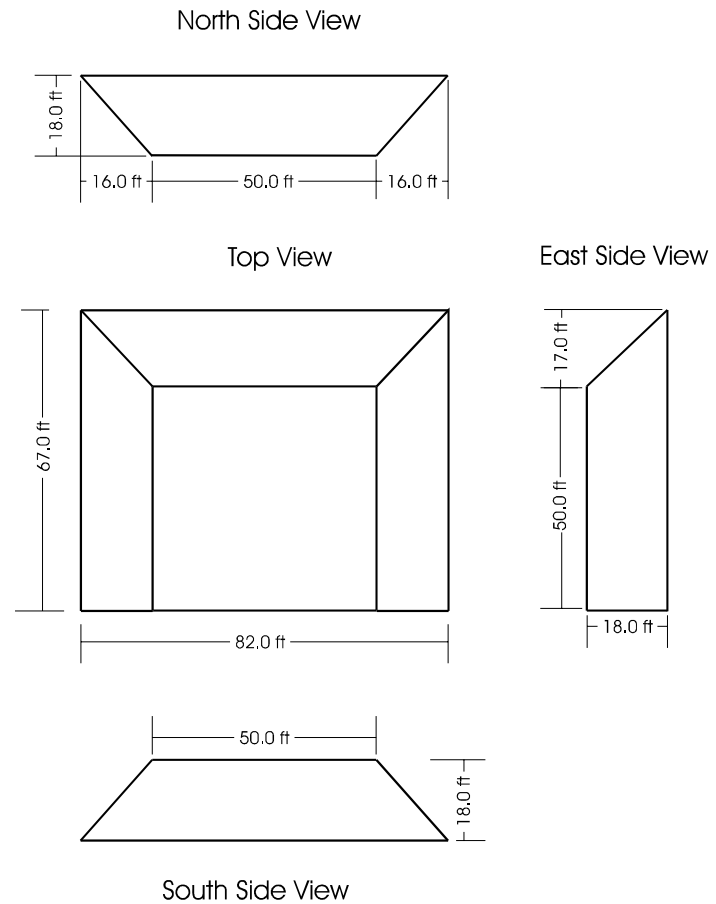
### ***11.2 Solar Envelope***

To protect a neighbor's right to the sun, each house and all items associated with the house and team lot must stay within the solar envelope shown in Figures 1 and 2.

Note: The official house height is the vertical distance from the point of highest grade along the outside perimeter of the house's footprint to the highest point of the house and its associated equipment. The official height of a site component is the vertical distance from the grade-level location directly beneath the highest point of the site component to the highest point of the site component.



**Figure 1: 3-D view of solar envelope**



**Figure 2: Solar envelope dimensions**

### ***11.3 House Sizing***

Houses are restricted to a maximum of 800 ft<sup>2</sup> (74.3 m<sup>2</sup>) of total building footprint. The perimeter of the projection of the house onto a horizontal plane from plan view cannot contain an area greater than 800 ft<sup>2</sup> (74.3 m<sup>2</sup>). Any house component (e.g., ADA ramps, HVAC condenser, decks, porches, wastewater tank, supply water storage container, and pressure pump) that is not part of the enclosed space and is not part of the solar array or energy storage system (see exception in Regulation 12.3) will be excluded from the 800-ft<sup>2</sup> (74.3-m<sup>2</sup>) footprint limitation but must be within the solar envelope. The house must have a minimum of 450 ft<sup>2</sup> (41.8 m<sup>2</sup>) of conditioned interior space measured as floor area from the inside of the exterior walls.

### ***11.4 Vegetation***

Teams are permitted to bring potted vegetation to enhance the aesthetic or energy characteristics of their houses, provided that the vegetation does not violate the solar envelope. Vegetation will not be considered part of the solar array. Vegetation may be placed and moved around each team's lot until the beginning of Contest Week. After that, the vegetation will remain stationary until the conclusion of all the Contests.

### ***11.5 House Entryways***

Teams have the freedom to place the main entry to their houses on any side of the house. However, teams must provide a walkway leading from the main street of the solar village to the main entrance of the house.

## **12. Energy**

### ***12.1 Generators***

Teams may provide a generator from which they may charge their energy storage devices or provide power to tools. Operation and refueling of generators is limited to times approved by the Organizers. Teams will be assessed significant penalties for generator usage during the Solar-Only Period, which is the period of time during which the use of nonsolar fuels is allowed, but not without a severe penalty. In general, penalties will be greater in proportion to increases in the length of a generator's run-time and in the amount of a generator's energy production. Penalties may be applied to specific Contests or to the overall score. Generators may be used only after notifying the Project Manager of the intention to use the generator.

Generators must be equipped with secondary containment systems that can accommodate all of the oil, fuel, and coolant that the generator contains at maximum capacities.

The table below lists the major phases of the Event, as well as the general ruling regarding the use of nonsolar fuel generators during each respective phase.

<i>Description of Event phase</i>	<i>Start day and time of Event phase</i>	<i>Ruling re: use of non-solar fuel generators</i>
Assembly	12:01 a.m. on 1 <sup>st</sup> day of Event (Thursday)	Allowed without penalty
Solar-Only before Contest Week	10:00 a.m. on 5 <sup>th</sup> day of Event (Monday)	Allowed with explicit Organizer approval and penalty (severe)
Solar-Only during Contest Week and before continuous measurements	8:00 a.m. on 10 <sup>th</sup> day of Event (Saturday)	Allowed with explicit Organizer approval and penalty (more severe)
Solar-Only during Contest Week and continuous measurements	8:00 a.m. on 12 <sup>th</sup> day of Event (Monday)	Allowed with explicit Organizer approval and penalty (most severe)
Disassembly	End of tour hours on 18 <sup>th</sup> day of Event (Sunday)	Allowed without penalty

### ***12.2 Solar Cell Technology Limitation***

Photovoltaics must be commercially available to all registered teams by the beginning of the Event at a price not to exceed US \$5 per watt (watt peak at Standard Test Conditions [STC]) for bare cells (teams may pay extra for cutting, tabbing, or lamination of the cells). For encapsulated modules, photovoltaics must be commercially available to all registered teams at a price not exceeding US \$10 per watt (watt peak at STC). Substantial modification of the crystal structure, junction, or metallization constitutes manufacture of a new cell and is not allowed.

### ***12.3 Energy Storage Location***

Energy storage devices (e.g., tanks, bladders, and mass components) must be located within the 800-ft<sup>2</sup> (74.3 m<sup>2</sup>) footprint. The house's primary battery bank and/or hydrogen storage vessels are exempt from this requirement. All associated equipment that would be removed along with the batteries and/or hydrogen storage vessels if the system were grid-tied after the competition is also exempt. Equipment is approved for exemption on a case-by-case basis. If the equipment is located within the physical boundaries of the primary house footprint, then the area it covers is not exempt. Exempt equipment and the enclosures that may be used to house exempt equipment are not exempt from evaluation by the Juries.



## ***12.4 Flywheel Storage***

No flywheels of any kind will be permitted for electrical or any other type of energy storage.

## ***12.5 Batteries***

Teams are allowed to use their houses and car battery systems for storage of electrical energy. The battery system for the car must be the car manufacturer's original equipment. Submittals of battery data shall be based on the manufacturer's published specifications provided by the team. Batteries must be available in sufficient quantities to be accessible to all participating teams. The battery modules may not be modified in any manner, for example, by using electrolyte additives; making case modifications; or adding, removing, or modifying plates. However, teams are permitted to add distilled water to vented (flooded) lead-acid batteries for maintenance purposes.

**Primary Batteries:** The use of primary (non-rechargeable) batteries is limited to smoke detectors, remote controls, thermostats, alarm clock backups, and other similar devices that contain small primary batteries.

**Secondary Batteries:** The use of small secondary (rechargeable) batteries for items such as laptop computers and PV walkway lights is permitted, provided that all such devices used for Contest purposes are to be recharged directly by a PV module(s) or from the house's electrical system. The Organizers will approve the use of small secondary batteries on a case-by-case basis.

## ***12.6 Energy Collection***

After the beginning of the Solar-Only Period, the only source of energy with which houses, tasks, and the electric cars will be permitted to operate is global solar radiation received by the house without artificial external augmentation. Direct radiation and diffuse radiation are considered forms of global solar radiation. All components used to convert global solar radiation to thermal, electrical, or mechanical energy shall be considered part of the solar array (see Regulation 12.7). The following exceptions to the Energy Collection regulation apply:

- Energy stored in the house battery system or other Contest-related secondary batteries (e.g., laptop batteries, and uninterruptible power supply systems) and the vehicle battery system when the Solar-Only Period begins
- Use of a generator or other nonsolar-power source to charge the electrical-storage system (see Regulation 12.1 for more details regarding generator usage)
- Additional water associated with the supply and consumption of energy above and beyond the water supplied at the beginning of the Contest.

## ***12.7 Solar Array***

At any given moment, the solar array comprises all components that are involved in the conversion of solar energy for use by the house, for tasks, and by the vehicle. In addition to direct energy conversion components (such as photovoltaic cells), the solar array includes any reflective surfaces, shading surfaces, refractive lenses, solar thermal collectors, or any means of passive solar collection. The solar array cannot be outside the 800-ft<sup>2</sup> (74.3 m<sup>2</sup>) footprint in any way. The entire solar array must be integrated into the structural envelope, or skin, of the building.

## ***12.8 Thermal and Electrical Storage System Sizing***

Thermal and electrical storage systems sized for annual loads may be very large and costly in contrast to those needed for the purposes of the Competition. Therefore, teams are permitted to present a house containing thermal and electrical storage systems that are downsized from, or smaller than, the sizing indicated by annual simulation results.

# **13. Water**

## ***13.1 Quantity***

In the drawings and specifications, teams must indicate all of the water that their entry requires during the Event.

## ***13.2 Supply***

The Organizers will supply teams with water after the beginning of the “solar only” period. All teams shall be ready to receive water before the water truck arrives on the Mall, so all team storage systems can be filled on the same day. Water will be supplied only once without penalty. After that, teams may request additional water, which may be subject to availability (indeterminable delay, depending on quantity needed) and a penalty. Instead of or in addition to a penalty, teams that delay the water supply process may be required to pay for their own water. Teams that are required to pay for their own supply water shall use a water-supply company approved by the Organizers.

Two gravity-fed water trucks will be available to fill the houses’ water storage systems. They will begin at the southwest and northeast corners and proceed counter-clockwise. The water trucks are restricted to gravel roads on the north and south sides of the Mall and are restricted in the height to which they can supply water. All water supply tanks must have easily accessible, 4-in. (10.2-cm) minimum diameter caps on the gravel road side of the house (north for teams on the north side of Mall, south for teams on the south side). All water tank caps must be less than 6 ft (1.83 m) from ground level. If teams have other water tanks higher than the 6-ft (1.83-m) cap limit, they

are required to pump the water to the higher storage tanks from a tank of their own that meets the 6-ft (1.83-m) cap limit. The water trucks can NOT supply water higher than 6 ft (1.83 m).

Teams should use a supply tank with enough capacity (plus an appropriate safety factor) to meet all their water needs throughout the Event. Contest requirements suggest a 250-gallon (946-liter) minimum; a team may require more, depending on appliances, cooking, and unforeseen events. To comply with Regulation 11.3: House Sizing, teams choosing to place their water supply storage container outside the 800-ft<sup>2</sup> (74.3-m<sup>2</sup>) footprint must prove to the Organizers in their Drawings and Specifications that the container is not part of the “solar array” or the “energy storage system.”

### ***13.3 Distribution***

Teams are responsible for distributing water within their houses. This includes all necessary pumps, tanks, lines, valves, etc. All pumping power to distribute water must come from the house energy system.

### ***13.4 Rainwater Collection***

After Assembly is completed, teams may gather rainwater in their building footprints and use this water for any purpose. See Section 10.8 of the Solar Decathlon Building Code for system requirements.

### ***13.5 Thermal Mass***

Any water used for thermal mass must be contained in a stand-alone system, which will be sealed off after the initial filling. Teams may use water as thermal mass to substitute for more common materials such as concrete masonry units (CMUs), concrete floor slabs, or brick. Water used for this purpose cannot be mixed with any other substance. Water will be supplied for thermal mass purposes and will have the same requirements as those for supply water.

### ***13.6 Evaporation***

Teams may use water for evaporation purposes. Water supplied by the Organizers that will be used for evaporation must be included in the water use estimation.

### ***13.7 Watering Vegetation***

Water from the house water system may be used to water any potted vegetation associated with the house. Prior to water delivery, teams are permitted to provide their own water for watering vegetation. Vegetation that will be consumed during the Event shall be watered with potable water, rainwater, or water supplied by an approved rainwater collection system only.

### ***13.8 Wastewater***

The wastewater tank must have a minimum 4-in. (10.2-cm) diameter cap that is no higher than 6 ft (1.83 m) from ground level, is easily accessible, and is located on the gravel-road side of the house. Teams are not required to place the wastewater tank within the 800-ft<sup>2</sup> (74.3-m<sup>2</sup>) footprint, but the tank must be located within the solar envelope.

### ***13.9 Wastewater and Thermal Storage Water Removal***

During Disassembly, all wastewater and thermal storage water shall be removed by a wastewater truck in a manner similar to the way in which the water was delivered. The wastewater truck will be equipped with a pump to aid in removal. Two wastewater trucks will begin at the northwest and southeast corners of the Solar Village and proceed clockwise in emptying wastewater and thermal storage tanks. Teams that delay the wastewater removal process may be required to pay for their own wastewater removal. Teams that are required to pay for their own wastewater removal shall use a company approved by the Organizers. Refer to [Section 3.11](#) of the Solar Decathlon Building Code for wastewater tank capacity requirements.

## **14. Electric Car**

### ***14.1 Pushing and Pulling***

In no case shall regenerative braking be engaged while pushing or pulling the car. The team's car may not be pushed or pulled during Contest hours except for the following situations:

- **Emergency:** In an emergency or breakdown situation, the car must be removed from the road. In this circumstance, the car may be towed back to Headquarters for inspection and repair.
- **Accidents and Re-inspection:** All accidents involving the car or support vehicles must be reported immediately to Solar Decathlon Headquarters. In case of an accident involving personal injury or property damage (or both), notification of the appropriate emergency medical services and public safety officials shall take priority. Notification to the school's insurer shall be made as soon as practicable. If a car is involved in an accident, it must be re-inspected by an Inspector before reentering the Contest. The Inspector may require that repairs be made before the team can resume the Contest.
- **Impound:** It may be necessary to push or pull the car to the impound area.

## ***14.2 Driver Requirements***

Only Decathletes are allowed to drive the team's electric vehicle for Contest 10: Getting Around Activities. All drivers at all times must have a valid driver's license and be 18 years of age or older.

Teams are required to include at least one passenger for all driving activities. During Contest 10: Getting Around Activities, that one passenger must be a Decathlete who has a means of communicating with the Decathletes remaining at the team's house. Teams must provide their own means of safe communication while operating the electric car. At all other times during the Event, that one passenger must be a Decathlete, Contest Official, member of the Event Staff, Judge, Juror, Inspector, Observer, Organizer, Rules and Regulations Committee member, or other person associated with the Solar Decathlon. Teams may have more than one passenger (provided they have one seat and safety belt per passenger), but at least one passenger must meet the requirements described here. All passengers at all times must have a valid driver's license and be 18 years of age or older.

## ***14.3 The Car***

Organizers will supply each team with an electric car. Proof of insurance must be kept with the vehicle at all times. Teams shall not make any alterations that could possibly improve the performance of the car. Minor cosmetic improvements, such as the application of team logos or the installation of stereo systems, may be approved by Organizers on a case-by-case basis. The replacement of car components with identical components is permitted. Teams may start the Contest with fully charged batteries in the vehicle, but any subsequent recharging must be supplied from energy generated by the house.

## ***14.4 Inspections and Accessories***

Before the team will be allowed to compete with its car, the car will be checked for compliance with the following manufacturer's specifications:

- Battery
- Tires
- Drive system
- Charging system
- Brakes
- 12-volt system (lights, horn, power plug).

The car also must have the following accessories installed at the Competition:

- Charge port locks

- Batteries sealed and marked to provide ready evidence of tampering after the start
- A logbook assigned to each vehicle that will provide written backup documentation to all vehicle activity
- Event decals supplied by Solar Decathlon Organizers.

## **15. Desiccant Systems**

If a desiccant system is used in the house, it must be regenerative. To ensure that desiccant systems function in a steady-state fashion, the desiccant material or device must be easily weighable. The device or material will be weighed before and after the Contests. Teams will be assessed a penalty at the end of the Contests for having a desiccant material or device that weighs more than its initial weight. Some desiccant systems with very low moisture storage capacities may be exempt from this requirement. Exemptions will be granted on a case-by-case basis.

## **16. Appliances**

The appliances used in Contest 6: Appliances, must meet the following requirements. Appliances that do not meet the following requirements may not be eligible for points in the particular Contest Activity with which they are associated.

### ***16.1 Refrigerator/Freezer***

Each team must provide a refrigerator and freezer with a minimum of 15 ft<sup>3</sup> (0.425 m<sup>3</sup>) combined interior capacity. Any attached freezer compartment must have a separate door from that of the refrigerator compartment and a minimum of 3 ft<sup>3</sup> (0.085 m<sup>3</sup>) interior capacity. Teams must submit manufacturers' specifications for the refrigerator and freezer's interior volume. Determination of compliance with this regulation is based on the volumes listed in the manufacturers' specifications. For custom refrigerators, teams must submit volume calculations based on the Association of Home Appliance Manufacturers (AHAM) standard, AHAM HRF-1-2001.

Teams may disable the automatic defrost function on their refrigerators and freezers and may use the refrigerator and freezer to store a reasonable amount of food and beverage for general team consumption and consumption during the cooking tasks. The use of an integrated icemaker is allowed only after the Contest Week begins.

### ***16.2 Clothes Washer***

The "Clothes Washing" Contest Activity of Contest 6: Appliances, requires teams to wash 12 large cotton bath towels on several occasions. Teams must use residential-sized washing machines that operate automatically and have both a wash and rinse cycle. For combination washer/dryer units, the cycle must be able to be interrupted at the conclusion of the wash cycle and before the initiation of the dry cycle to allow for removal of the temperature sensor.

### ***16.3 Clothes Drying***

The drying method may include active drying (e.g., machine-drying), passive drying (e.g., on a clothes line), or any combination of active and passive drying. All drying methods that require the towels to be visible must be demonstrated to the Architecture and Market Appeal Juries as they tour the houses.

### ***16.4 Dishwashers***

Dishwashers must have a minimum capacity of six place settings according to the manufacturer's specifications. A single place setting is defined as a dinner plate, a salad plate, a bowl, a cup and saucer, two forks, a knife, and a spoon. Dishwashers must operate automatically and must have a wash and a rinse cycle. If a heated dry cycle is to be used, the temperature sensor must be able to be removed prior to the initiation of the heated dry cycle.

### ***16.5 Video Display***

The video display must be a minimum of 19 in. (48.3 cm) according to the manufacturer's stated display size. The computer and video displays shall be able to be operated simultaneously and controlled independently of each other.

### ***16.6 Computer Display***

The computer display must be a minimum of 17 in. (43.2 cm) according to the manufacturer's stated display size. The computer and video displays shall be able to be operated simultaneously and controlled independently of each other. The computer may be a notebook, laptop, or desktop computer.

## **17. Preliminary Event Schedule**

The preliminary event schedule may be used for planning purposes, but is not complete and may not be up to date. Any items noted in the preliminary schedule are subject to change at any time. A detailed event schedule will be provided via the Yahoo! Group. Teams are required to have their houses open during public tours, but it should be noted that the village will be closed during one of the days of "possible public tours" as noted in the preliminary schedule. The specific day will be selected closer to the Event and will be noted in the detailed schedule on the Yahoo! Group.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
NOTES: 1) Items in <b>BOLD</b> occur during solar-only period (10 a.m. on Day 5 to 5 p.m. on Day 18). 2) This is preliminary schedule and may not be complete or up-to-date. It is subject to change at any time. Refer to the detailed schedule posted on the Yahoo! Group for a comprehensive, up-to-date list of activities.				Day 1  ASSEMBLY (12:01 a.m. – midnight)	Day 2  ASSEMBLY (24 hours)	Day 3  ASSEMBLY (24 hours)
Day 4  ASSEMBLY (24 hours)	Day 5  ASSEMBLY (midnight – 10 a.m.)  <b>FINISH WORK and COMMISSIONING</b> (10 a.m. – midnight)	Day 6  <b>FINISH WORK and COMMISSIONING</b> (24 hours)	Day 7  <b>FINISH WORK and COMMISSIONING</b> (24 hours)	Day 8  <b>FINISH WORK and COMMISSIONING</b> (24 hours)	Day 9  <b>FINISH WORK and COMMISSIONING</b> (midnight – 9 a.m.)  <b>OPENING CEREMONY</b> (9 a.m. – 11 a.m.)  <b>VIP TOURS</b> (11 a.m. – 3 p.m.)  <b>IMPOUND</b> (8 p.m. – midnight)	Day 10  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 6 p.m.)  <b>PUBLIC TOURS</b> (10 a.m. – 5 p.m.)  <b>IMPOUND</b> (8 p.m. – midnight)
Day 11  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 6 p.m.)  <b>PUBLIC TOURS</b> (10 a.m. – 5 p.m.)  <b>IMPOUND</b> (10 p.m. – midnight)	Day 12  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 9:30 p.m.)  <b>POSSIBLE PUBLIC TOURS</b> (11 a.m. – 3 p.m.)  <b>IMPOUND</b> (10 p.m. – midnight)	Day 13  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 9:30 p.m.)  <b>POSSIBLE PUBLIC TOURS</b> (11 a.m. – 3 p.m.)  <b>IMPOUND</b> (10 p.m. – midnight)	Day 14  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 9:30 p.m.)  <b>POSSIBLE PUBLIC TOURS</b> (11 a.m. – 3 p.m.)  <b>IMPOUND</b> (10 p.m. – midnight)	Day 15  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 9:30 p.m.)  <b>POSSIBLE PUBLIC TOURS</b> (11 a.m. – 3 p.m.)  <b>IMPOUND</b> (10 p.m. – midnight)	Day 16  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>CONTESTS</b> (8 a.m. – 1:30 p.m.)  <b>PUBLIC TOURS</b> (11 a.m. – close)  <b>AWARDS CEREMONY</b> (2 p.m. – 2:30 p.m.)  <b>IMPOUND</b> (8 p.m. – midnight)	Day 17  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>PUBLIC TOURS</b> (10 a.m. – 5 p.m.)  <b>VICTORY RECEPTION</b> (6 p.m.)  <b>IMPOUND</b> (8 p.m. – midnight)
Day 18  <b>IMPOUND</b> (midnight – 7 a.m.)  <b>PUBLIC TOURS</b> (10 a.m. – 5 p.m.)  DISASSEMBLY (5 p.m. – midnight)	Day 19  DISASSEMBLY (24 hours)	Day 20  DISASSEMBLY (24 hours)	Day 21  DISASSEMBLY (24 hours)			



## The Contests

The Solar Decathlon Competition consists of 10 separately scored Contests. Contests contain one or more Contest Activities. For example, Contest 5: Comfort Zone consists of two separately scored Contest Activities. The team with the highest total points at the end of the Competition will win. The table below lists the 10 Contests and the point values assigned to each.

Contest Number	Contest Name	Available Points
1	Architecture	200
2	Engineering	150
3	Market Viability	150
4	Communications	100
5	Comfort Zone	100
6	Appliances	100
7	Hot Water	100
8	Lighting	100
9	Energy Balance	100
10	Getting Around	100
<b>TOTAL</b>		<b>1200</b>

There are three ways to earn points. Most Contest Activities are one of the following three types, but some of the Contest Activities are a combination of two types.

- Successful task completion
- Continuous performance measurements
- Subjective jury evaluation.

Contest Activities based on successful task completion and/or continuous performance measurements are also called “objective” Contest Activities. Contest Activities based on a subjective jury evaluation are also called “subjective” Contest Activities.

Points for successful task completion are generally awarded as a function of “closeness to completion.” Points for continuous performance measurements are either awarded every 15 minutes during scored periods of the Event, at the end of each day, or at the conclusion of the Contest Week when performance requirements are met or partially met. To clarify, “scored periods” include all the 15-minute increments between the official start time on the first day of continuous measurements and the official finish time on last day of continuous measurements, with the exception of those periods during which scoring is suspended for public tours. Public tour schedules will be published in the Event Schedule.

The scoring of the subjective Contest Activities is more flexible than the scoring of the objective Contest Activities described above. However, for the sake of fairness, it is important that there is consistency. To encourage consistency among all the subjective Contest Activities, the Jurors will be encouraged to use the evaluation method described in the [Subjective Contest Activity Guidelines for Jurors and Teams](#).

## Contest 1: Architecture

This contest considers aspects of architecture that are not comprehensively evaluated in the objective contests, i.e., Contests 5 through 10.

### *Architecture Design and Implementation (150 pts):*

The Architecture Jury will evaluate the houses according to the following principles:

#### *Firmness:*

- Strength, suitability, and appropriateness of materials for the building
- Balance between the need for solidity and strength and the challenge of portability and ease of construction
- Integration of structure and enclosure.

#### *Commodity:*

- Ease of entry into the house and circulation among the public and private zones of the house, as well as the served and service spaces
- Architectural strategy used to accommodate the technologies (especially the photovoltaic array) required to run the house
- Generosity and sufficiency of space to allow all of the activities required during the Contests to take place.

#### *Delight:*

- Surprises, unusual use of ordinary materials, or use of extraordinary materials
- Sufficiency of architectural attention given to the experiential relationship between inside and outside
- Lasting impression: Is the house memorable in any way? In the interior? From the exterior?
- Balance of attention paid to all sides of the house.

**Drawings and Specifications (50 pts):**

The Architecture Jury will judge the construction drawings and specifications according to the following criteria:

- Efficiency
- Organization
- Comprehensiveness
- Quality
- Creativity.

<b>Contest Activity</b>	<b>Points Available</b>
Architecture Design and Implementation	150
Drawings and Specifications	50
<b>TOTAL</b>	<b>200</b>

## Drawings and Specifications Contest Activity Details

Teams are required to submit drawings and specifications on four separate occasions. Ideally, the drawings and specifications are continual works-in-progress that culminate in the as-built submittal, which is one of the final contract deliverables due after the Competition. The Organizers use the drawings and specifications for many purposes throughout the Project. The following is a brief description of each of the four required sets of drawings and specifications.

1. **Design Development Drawings and Specifications (due June 13, 2006):** The following description of the design development project stage is taken directly from *The Architect's Handbook of Professional Practice: Student Edition*:

“Decisions made in schematic design are worked out at a more detailed level to minimize the possibility of major modifications being needed during the development of construction contract documents. In design development the design team works out a clear, coordinated description of all aspects of the design, including architectural, mechanical, electrical, plumbing, and fire protection systems. Deliverables are similar to those of schematic design but are more detailed. They include drawings and specifications, an updated cost estimate, and, if required, the preparation of estimated schedules for construction. Again, written client approval provides a basis for subsequent work. The approved design development documents provide the basis for the construction documents increment, which sets forth in detail the requirements for construction.”

The Organizers will evaluate the design development set to determine whether a team will receive conditional approval (analogous to the statement above, “written client approval provides a basis for subsequent work”). The Organizers will thoroughly review the information contained in this set and identify any deficiencies and requirements for final approval.

2. **Construction Drawings and Specifications (due March 6, 2007):** The following description of the construction documents project phase is taken directly from *The Architect's Handbook of Professional Practice: Student Edition*:

“Once a design has been developed and approved, the architect prepares the drawings and specifications that set forth the requirements for construction. The development of the construction documents is an extension of the design process. Decisions on details, materials, products, and finishes all serve to reinforce the design concept—and begin the process of translating the concept into reality.

The drawings show, in graphic and quantitative form, the extent, configuration, location, relationships, and dimensions of the work to be done. They generally contain site and building plans, elevations, sections, details, diagrams, and schedules. In addition to drawn information, they may include photographs, other imported graphics, and printed schedules. Architectural, structural, mechanical, electrical, civil, landscape, interior design, and other applicable specialty drawings should be included.

The specifications outline the levels of quality and the standards to be met in the construction process. Addenda include additional information that is not covered by drawings or specifications. The set of construction documents should communicate to the contractor the quantities, qualities, and configuration of the elements required to construct a project.”

The construction set should address the deficiencies and requirements identified by the Organizers in the design development set review. If the construction drawings and specifications are satisfactory, a team will receive final approval. If significant deficiencies remain, updated construction drawings and specifications (see #3 below) must be sent to and reviewed by the Organizers before final approval can be granted. Teams that do not receive final approval may be asked to withdraw from the Competition.

3. **Updated Construction Drawings and Specifications (due August 7, 2007):** This deliverable is mandatory only if a team did not receive final approval based on the Organizers’ review of the original (March 6<sup>th</sup>) construction drawings and specifications. Otherwise, this deliverable is optional. However, teams that make significant design changes after March 6<sup>th</sup> are strongly encouraged to submit updated construction drawings and specifications to avoid potential problems during building inspections on the Mall. Teams that want to improve on their original construction drawings and specifications may also choose to submit an updated version for contest purposes. The Architecture Jury will evaluate and score one and only one set of drawings and specifications. If mandatory or optional updated construction drawings and specifications are not submitted, the Jury will evaluate the original construction drawings and specifications.
4. **As-Built Drawings and Specifications (due January 9, 2008):** The following is a description of as-built drawings and specifications from [H-K Resources Pte Ltd](#).

“As-Built Drawings depict the final installed configuration (whether physical or functional). They indicate any construction deviations and show all features of the project as actually built. These drawings provide a permanent record of as-built conditions and aid as key references for future maintenance processes.”

Because it is due after the Competition, the as-built set will obviously not count toward a team’s score. However, the as-built set is a very important contract deliverable and shall reflect the final installed configuration of the house on its permanent site.

## Minimum Content Requirements

No definition of the specific required content of construction documents exists. The following minimum content requirements are a guide to assist in organizing work effort. Additional content may be required or desired depending upon the requirements of specific designs.

Creativity applies to preparation of construction documents as much as to aesthetic decisions about designs. Effective modern construction documents tell a thorough story that allows the builder of the project to understand the design. Modern designers have excellent tools that allow communication of construction details in three dimensions augmenting ease of use of the construction documents. Teams are encouraged to explore three dimensional communication, photography, color and texture, as well as traditional plans, elevations, sections, and details in their construction documents presentations.

The **drawings** must include the following:

- *Table of Contents:* (This table should appear on the first page after Cover Sheet)
- *Site Plan and Elevations:* Show the placement of the house and exterior tour route within the Solar Envelope and show the locations of the car, water tanks, walkways, signs, vegetation, and all other site features. Elevations (or dimensioned 3-D views) are required for verification of compliance with the 18-ft. height rule.
- *Footprint and Conditioned Area Plan:* Clearly show estimated areas (using a program such as Brava Reader) for compliance with Event Regulation 11.3: House Sizing.
- *Architectural:* Include plans, elevations, and sections.
- *Structural:* Drawings shall be stamped by a Professional Engineer (PE) and demonstrate compliance with structural requirements in the Solar Decathlon Building Code.
- *Electrical:* Include sufficient detail to size and locate major components with the associated routing of conduit and duct systems for electrical power service and distribution, PV systems, lighting, data communication, lightning protection, ground fault protection, and data acquisition and control systems. Includes one-line diagrams. Demonstrate compliance with electrical requirements in the Solar Decathlon Building Code.
- *Mechanical and Plumbing:* Include sufficient detail to size and locate major components with the associated routing of piping, ducts, and plenums for plumbing, HVAC, and hot water heating systems. Demonstrate compliance with mechanical and plumbing requirements in the Solar Decathlon Building Code.
- *Accessibility:* Demonstrate compliance with the accessibility requirements in the Solar Decathlon Building Code. Show interior tour route.
- *Layouts:* Must contain sufficient detail to identify the layout of spaces, systems, furniture, and equipment, including material selections with colors, textures, finishes, etc.
- *System Schematics:* Include schematics of solar electric, hot water heating, and other unique or unusual systems.

- *Assembly Process*: Illustrates the assembly process, specifies the equipment to be used on site to aid the assembly process (e.g., cranes, forklifts), and estimates the time necessary to deliver and assemble the house.
- *Disassembly Process*: Illustrates the disassembly process, specifies the equipment to be used on site to aid the disassembly process (e.g., cranes and forklifts), and estimates the time necessary to disassemble and remove the house from the Mall.
- Other important drawings not included in this list.

The **specifications** must include the following:

- Table of Contents: Even equipment specification sheets shall have page numbers and be included in the table of contents.
- Summary of changes: If there are changes to the drawings and specifications between the design development set and the construction set, provide a summary of those changes with the construction set. If there are changes to the drawings and specifications between the original construction set and the updated construction set, provide a summary of those changes with the updated construction set.
- Structural calculations: These shall be stamped by a P.E.
- Solar cell specifications:
  - Copy of manufacturer's solar cell and module specification sheet(s)
  - Manufacturer's name and contact information
  - Stock number, type, or description
  - Manufacturer's quote for cell or module area
  - Manufacturer's quote for performance
  - Cost (US\$) per watt for each cell or module.
- Battery specifications:
  - Copy of manufacturer's battery specification sheet(s)
  - Material Safety Data Sheets (MSDS) obtained from the manufacturer
  - Manufacturer's name and contact information
  - Stock number, type, or description
  - Module voltage (e.g., 6 V, 12 V, or 24 V)
  - Bus voltage
  - Number of modules to be used in the house
  - Manufacturer's specifications, including capacity (kWh), weight (lb.), and cost (US\$)
  - Spill and damage protocols and procedures (if these are not provided in the MSDS, the team must obtain this information from the manufacturer and submit it with the MSDS).
- Information that is not included in the drawings, but is necessary to demonstrate compliance with the Solar Decathlon Building Code: For example, such information would include calculations showing that the battery enclosure ventilation is sufficient to maintain compliant hydrogen concentrations.



- Summary of unlisted electrical components and justifications for choosing unlisted components. Unlisted electrical components will be approved for use in the competition on a case-by-case basis.
- Manufacturers' data sheets for all major house components: These data sheets shall include, but not be limited to, kitchen appliances, hot water heating system components, water supply system components, solar electric balance of system components, HVAC system components, thermal storage devices and tanks, primary structural components, insulation, windows, and unusual finishes, fixtures, and furnishings.
- Material Safety Data Sheets (MSDS) required for all materials to be used at the Event that require an MSDS: These would include, for example, MSDS for cleaning solvents, glycol, rubber cement, rubbing alcohol, etc.
- Categorized inventory of water requirements: The Organizers need to know how much water is required to meet all the houses' needs during the Event.
- Any other important supplemental information not included in this list.

Note: Some information listed under the specifications requirements may be more appropriately located in the drawings as notes or tables. It is up to the teams to decide whether information belongs in the drawings or specifications. The Architecture Jury will evaluate how well the teams organize the information in the drawings and specifications.

## **Format Requirements**

- Drawings must be 11 in. X 17 in. (or closest metric equivalent).
- Specifications must be 8.5 in. X 11 in. (or closest metric equivalent).
- There are no page number limits. The Architecture Jury will determine whether an appropriate amount of information has been conveyed in the drawings and specifications.
- Spiral bindings are required for both the drawings and specifications. Do not separate either the drawings or specifications into multiple "parts." One complete set of drawings and specifications consists of one and only one spiral-bound set of drawings and one and only one spiral-bound set of specifications.
- Five (5) hard copies of the design development drawings and specifications, eight (8) hard copies of the construction (original and updated) drawings and specifications, and three (3) copies of the as-built drawings and specifications are required. In addition to the hard copies, electronic files of the drawings and specifications are also required. The electronic files must meet the following requirements. If they do not meet these requirements, they will not be used in any brochures, signs, programs, or other promotional materials:
  - Images must be 11 in. X 17 in. (or closest metric equivalent) at 300 dpi.
  - TIFF files are preferable, but EPS or Adobe Illustrator (Version 5.5 or higher) files are also acceptable. AutoCAD or similar files will not be accepted.

- Mac platform files are preferable, but PC platform files are also acceptable. Although problems with PC platform files are rare, they do sometimes occur, so if you want to make sure the Organizers can access your files, you should consider Mac platform files.
  - Files must be in RGB, 8-bit color.
  - Only compressed files using Stuffit or ZIP software will be accepted.
- A standard architectural title block must appear on the right side of every page of the drawing set. The title block may be toward the top, middle, or bottom of the page, but it must be placed on the right side.
- The scale of all plans (except Site Plan), elevations (except Site Elevations), and sections must be 0.25 in. = 1 ft-0 in. (or closest metric equivalent). However, a graphic scale must be used so that the drawing can be reduced or enlarged without consequence. The Site Plan and Site Elevations must be 0.125 in. = 1 ft-0 in (or closest metric equivalent).
- Construction details should be at an appropriate scale.
- There must be a 0.5 in. (or closest metric equivalent) margin around the entire page.
- Refer to *The Architect's Handbook of Professional Practice: Student Edition* for suggested drawing conventions regarding page numbers, text heights, layers, dimensions, symbols, specifications, etc.
- The cover sheet of the drawings set, to be used as quick reference by the Architecture Jury and the Dwelling Panel in their evaluations, must contain the following information:
  - Title
  - Floor plan
  - Site plan, i.e., location relative to other houses
  - Image of house exterior (can be a photo or computer rendering)
  - 250-word mission statement.
- Send the Drawings and Specifications package to the following address:
 

Mike Wassmer  
National Renewable Energy Laboratory  
Mail Stop 3214  
1617 Cole Blvd.  
Golden, CO 80401
- To be considered on time, the package must arrive at NREL by 5 p.m. Mountain time on the due date. Points will be deducted for lateness.

## Contest 2: Engineering

This contest considers aspects of engineering that are not comprehensively evaluated in the objective contests, i.e., Contests 5 through 10.

### ***Engineering Design and Implementation (100 pts):***

A jury of engineers will evaluate the house's building envelope, indoor environmental control, mechanical, electrical, and plumbing systems according to the following criteria:

- Functionality
- Efficiency
- Innovation
- Robustness
- Short- and/or long-term economic value.

### **Energy Analysis (50 pts):**

A jury of building energy simulation experts will evaluate the team's Schematic Energy Analysis Report, Final Energy Analysis Report, and Simulation Input Form. The Energy Analysis Jury will assess the team's use of simulation tools to inform design decisions and predict annual energy performance. Teams are encouraged to apply the concepts of whole building design during the design phase, including the use of computer simulations to model alternatives. The Jury will evaluate the report according to the following criteria.

- Assumptions: Significant assumptions regarding the analysis or simulation (or both) are identified
- Simplifications: The simulation is as simple as possible without compromising accuracy, and all significant simplifications are identified and justified
- Improvisation: Currently available software may not contain routines for all situations, and any necessary improvisations to simulate a specific component or system are documented and justified
- Energy performance: Design steps taken to optimize energy performance, including predicted annual energy requirements of the proposed design, are discussed.

The Jury will be looking for effective communication and synthesis of the team's design and analysis process with focus on the application of sound modeling and engineering principles and creative analysis according to the following criteria.

Communication:

- Effectively communicates the intended integration of building elements and systems
- Communicates the analysis steps supporting design recommendations, including parametric and optimization studies and custom and specialized analysis for specific components
- Demonstrates effective, creative use of graphics to condense and summarize key analysis
- Conveys the design process (architectural programming, design goals, and whole building strategies)
- Includes summary drawings of the plan and elevation to convey key geometrical and architectural information
- Demonstrates organization and consistency in main and supporting documents
- Innovative visual style enhances organization and access to report findings.

Engineering:

- Summarizes clearly the thermal and electric loads used in the analysis, and includes comparison or reference (or both) to standard load assumptions, such as *ASHRAE Standard 90.2*
- Summarizes clearly the key assumptions such as envelope characteristics, lighting level, and thermal set-points
- Demonstrates awareness and testing of design against “high performance” energy efficiency strategies
- Demonstrates awareness and attempt to integrate building architecture and systems
- Demonstrates innovative and creative analyses where standard tools are limited
- Identifies clearly the key assumptions and supporting information where engineering approximations are required
- Demonstrates quality control checks (e.g., order-of-magnitude analysis, corroborating data from multiple sources, sign-off by multiple reviewers) on component and overall analysis.

Contest Activity	Points Available
Engineering Design and Implementation	100
Energy Analysis	50
<b>TOTAL</b>	<b>150</b>

## Energy Analysis Contest Activity Details

Teams are required to submit a total of four energy analysis deliverables. However, only the first three deliverables will be evaluated by the Energy Analysis Jury. The Jury will generate a single score for the Energy Analysis Contest Activity based on its evaluation of the Schematic Energy Analysis Report, the Comprehensive Energy Analysis Report, and the Simulation Input Form. The Jury will be looking for effective communication and synthesis of the team's design and analysis process, focusing on the application of sound modeling and engineering principles and creative analysis.

The following is a brief description of each of the required deliverables.

1. **Schematic Energy Analysis Report (due June 13, 2006):** This report is intended to summarize the preliminary, or “schematic,” energy analysis supporting the development of the team's house design. Discussion should highlight key features of the house design that were affected by energy analysis and simulation results. A typical discussion of key features of the design would include annual energy source estimates (e.g., PV and solar thermal); annual energy load estimates, including lighting, heating, cooling, and domestic hot water heating; and other loads (e.g., electric car charging). Additional overall results worthy of discussion could include Event site climate statistics, predicted monthly energy balance (energy collected versus energy used), space temperatures, or other indicators chosen to highlight the energy performance of the design.
2. **Comprehensive Energy Analysis Report (due August 7, 2007):** This report shall consist of two sections:

*Section I – Influence of Energy Analysis on House Design and Competition Strategy:* The objective of the Schematic Energy Analysis Report was to summarize the schematic energy analysis supporting the development of the team's original house design. During the period of time since the submission of the Schematic Energy Analysis Report in June 2006, it is likely that teams have continued to use energy analysis tools and techniques to iteratively “fine-tune” the house design, to develop detailed system designs, and perhaps even to develop competition strategies. Section I of the Comprehensive Energy Analysis Report should describe how energy analysis was used to inform design and strategy decisions since the submission of the Schematic Energy Analysis Report.

*Section II – Projected Performance of Final House Design on an Annual Basis:* Simulation tools are not only used to inform design decisions. They are also used to project the long-term performance of the design. Long-term energy simulations are often used to extol the virtues of new technology and advanced design before actual energy performance data has been collected. Of course, one must avoid the temptation to present overly optimistic projections based on unrealistic assumptions, lest the design gain a reputation for being “overrated” after long-term energy performance data has been collected. Section II of the Comprehensive Energy Analysis Report should include long-term projections (simulations over a 1-year time period are typical) of the house's energy performance. Teams are encouraged to project energy performance on both a whole-house basis and system-

by-system basis by simulating the performance of all the house's energy-producing and energy-consuming systems. Results should be reported for a range of geographic locations and occupancy behavior patterns.

3. **Simulation Input Form (due August 7, 2007):** To enable side-by-side comparisons among all the houses, teams are required to complete a form that asks for all the detailed house and system information required to run a comprehensive whole-building energy simulation. In addition to using the form to generate inputs for building energy simulations of the houses before and after the Competition, the Organizers will also use the form to generate a summary of all major systems and equipment that will be published in the 2007 Solar Decathlon Technical Report and other publications. The Simulation Input Form will be developed by the Organizers and posted on the Yahoo! Group.
4. **Updated Simulation Input Form (due January 9, 2008):** Because it is due after the Competition, the Updated Simulation Input Form will obviously not count toward a team's score. However, this is a very important contract deliverable and shall reflect the final installed configuration of the house and its systems on the permanent house site.

## Format Requirements

- There are no restrictions on the simulation tools that can be used for this analysis, but all such tools should be clearly identified.
- One electronic copy (Microsoft Word document or Adobe PDF for reports and Microsoft Excel for simulation input forms) of each deliverable must be uploaded to the appropriate team folder on the Solar Decathlon FTP site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/Team\\_Folders/](ftp://ftp.nrel.gov/pub/solar_decathlon/Team_Folders/)) or e-mailed directly to Mike Wassmer at [michael\\_wassmer@nrel.gov](mailto:michael_wassmer@nrel.gov) on the respective due date by 5 p.m. Mountain time. Points will be deducted for lateness.
- The main body of the Schematic Energy Analysis Report may not exceed 15 single-sided pages, using a single-spaced 11-pt font. The pages must be 8.5 in. X 11 in. (or closest metric equivalent) and may include any embedded building plans and graphics that are appropriately placed in the body of the report. Appendix material (e.g., data sheets, simulation results, and screen captures) may be included, if desired. The appendices should have the same format as the body of the report and may not exceed 15 pages.
- The main body of the Comprehensive Energy Analysis Report may not exceed 25 single-sided pages, using a single-spaced 11-pt font. The pages must be 8.5 in. X 11 in. (or closest metric equivalent) and may include any embedded building plans and graphics that are appropriately placed in the body of the report. Appendix material (e.g., data sheets, simulation results, and screen captures) may be included, if desired. The appendix should have the same format as the body of the report and may not exceed 25 pages.

## Contest 3: Market Viability

### ***Market Appeal (50 pts):***

A Jury of homebuilders will evaluate the responsiveness of the team's project to the demands of a defined target market.

The Market Appeal Jury will consider the following criteria:

- *Livability*: A livable home makes it easy to perform everyday living tasks with a minimum of effort, and a maximum of safety. The home is built to be operated and maintained efficiently and economically.
- *Buildability*: A home possessing the quality of "buildability" can be constructed efficiently and cost-effectively. Buildability is part of creative design and leads to benefits for clients, designers, and builders. Attention by the designer can help the builder achieve quality, speed, and economy when building a home.
- *Flexibility*: A flexible home design can be adapted to accommodate the range of subjective tastes, practical needs, budgets, household sizes, and demographics within the defined target market. After it is designed and built, a flexible home can be adapted to accommodate lifestyle changes.

### **Economic Analysis (50 pts):**

A jury of experts will evaluate the economic effectiveness of the building-integrated photovoltaic (BIPV) design, and the team's ability to effectively utilize economic optimization and evaluation techniques to inform design decisions. The Jury will also evaluate the team's cost estimate of a marketable version of its competition house.

The following specific criteria will be emphasized:

- *Cost estimating*: The cost estimate of a marketable version of the prototype house and its energy systems is appropriately detailed and accurate, and is organized and reported per the requirements listed in [Economic Analysis Contest Activity Details](#)
- *Assumptions*: Significant assumptions regarding the analyses are identified
- *Simplifications*: The analyses are as simple as possible without compromising accuracy, and all significant simplifications are identified and justified
- *Improvisation*: Currently-available software tools may not contain routines for all situations. Any necessary improvisations to perform the analyses are documented and justified
- *Economic performance*: A creative and effective building-integrated approach for reducing the levelized cost of energy (LCoE) generated by the PV system is designed, implemented, and justified; opportunities to optimize the economic performance of all

house components that affect the house's overall energy performance are identified, and the effect that optimization results had on design decisions is discussed.

***Project Deliverables (25 pts):***

Contest Organizers will evaluate the timeliness, completeness, detail, accuracy, and overall quality, of a series of project deliverables submitted prior to the Competition. Project deliverables include [project summaries](#), project cost summaries, preliminary [drawings and specifications](#), preliminary [economic analysis and cost estimates](#), safety plan, site operations plan, [dinner menu](#), and other items identified on the Yahoo! Group Calendar as “DELIVERABLE” or “DEADLINE.”

Attendance at meetings and on conference calls and responsiveness to information requests are also considered project deliverables and will be evaluated accordingly. The Organizers reserve the right to add or remove deliverables at any time.

***Code and Regulation Compliance (25 pts):***

The safety officials, building inspectors, site operations staff, and members of the Rules and Regulations committee will evaluate the team's [safety practices](#), ability to expeditiously pass [building inspections](#), and compliance with [National Park Service](#) and [Competition Regulations](#) during the Event. Serious violations may be subject to an additional penalty per [Regulation 6: Penalties](#).

Contest Activity	Points Available
Market Appeal	50
Economic Analysis	50
Project Deliverables	25
Code and Regulation Compliance	25
<b>TOTAL</b>	<b>150</b>



## Economic Analysis Contest Activity Details

In this Contest Activity, teams are required to do the following:

1. Generate a realistic cost estimate for a marketable prototype version of the competition house
2. Present the results of an analysis justifying the economic benefits of the building integrated photovoltaic (BIPV) solution(s)
3. Use building energy optimization techniques to identify a suite of economically-appropriate energy-efficiency measures (EEMs) that may be used to inform design decisions.

### *Marketable Prototype Cost Estimate*

Assume that this estimate is part of a bid package submitted to a client interested in purchasing a marketable prototype version of the competition house. The team should think of itself as a homebuilder assembling a bid for a client within the team's target market. The "competition house" is the house a team brings to the competition. A "marketable prototype" is a hypothetical version of the competition house. Some marketable prototype costs may be lower than the competition house costs, because systems and features that may have been custom designed for the competition house are assumed to have become commercially available. In this case, teams shall document the rationale for cost decreases. Specific instructions follow:

- Estimates shall be organized according to the [2004 MasterFormat standard](#).
- Teams may use the software package of their choice for cost estimating and reporting purposes.
- Teams may use the cost database of their choice to estimate unknown costs.
- Teams are encouraged to consult a book, such as Wayne J. DelPico's [Estimating Building Costs](#), published by RSMeans, or consult with a professional cost estimator to get a feeling for the types of information and level of detail in a typical cost estimate. Note that materials estimates are only one of several components of a typical cost estimate.
- The Organizers will use the building cost estimate to create a "Product Directory" for the general public. The [2005 Solar Decathlon Product Directory](#) can be accessed on the Web. To facilitate the development of the Product Directory, the cost estimate shall include all information that a member of the general public would need to purchase a product for his or her own do-it-yourself project. Ordinary parts, such as nuts and bolts, that can be purchased at any hardware store or home center are excluded from this requirement.
- The "Procurement and Contracting Requirements" division (Division 00) of the 2004 MasterFormat standard need not be included in the estimate.

## ***BIPV Economic Analysis***

In his 2006 State of the Union Address, President Bush introduced the [Solar America Initiative](#) (SAI). The primary goal of the Initiative is to make the cost of solar-generated electricity competitive with the cost of electricity generated with conventional energy sources. Because [BIPV](#) systems have the potential to reduce the effective cost of a PV system by reducing or eliminating the costs of the building components they replace, BIPV is expected to make a major contribution toward the initiative's cost-reduction goals for systems installed on residential and commercial buildings.

Teams are challenged to utilize existing BIPV equipment and design solutions or to develop new equipment and solutions (or both) to reduce the levelized cost of energy generated by their PV systems ( $LCoE_{PV}$ ). To justify their BIPV approaches, teams are required to use a PV simulation tool and the [LCoE calculator](#) to determine the  $LCoE_{PV}$  in Phoenix, Arizona, Washington, D.C., and a third location of the team's choosing. If the economic analysis was optimized for a particular location, that location should be chosen as the third location.

The Economic Analysis Jury will assign the highest scores to teams whose BIPV designs most effectively reduce the  $LCoE_{PV}$ . The Jury will not base its decision solely on the reported  $LCoE_{PV}$ , because the  $LCoE_{PV}$  can be affected by factors unrelated to the effectiveness of the BIPV design. Creativity and market potential of the BIPV design will be emphasized more heavily than reaching a low  $LCoE_{PV}$ , if the low cost is not primarily attributable to the BIPV design.

Procedure for calculating the  $LCoE_{PV}$  using the LCoE Calculator:

1. Enter cost and rating information in the first five green cells.
2. Enter the results of the annual PV simulation into the green "PV system energy production in 2007" cell. Note that the PV de-rating factor shall be included in the team's simulation.
3. Choose a location that matches the simulation location.
4. Record the  $LCoE_{PV}$ , which is located in the "Marketable Prototype" box.

## ***EEM Economic Analysis***

A critical long-range outcome of the Solar Decathlon project is the development and demonstration of solar-powered homes in which, by the year 2015, the whole-house, levelized energy cost has been reduced to \$0.10/kWh, while complying with the criteria associated with the ten contests that make up the competition. Teams are encouraged to work toward this goal by identifying EEMs through the use of building energy optimization methods (a [paper describing one building energy optimization method](#) is posted on the Yahoo! Group) and by using the results of their building energy simulations and building cost estimates to calculate the whole-house levelized energy cost ( $LCoE_{WH}$ ) for benchmarking purposes. The  $LCoE_{WH}$ s calculated by the 2007 teams will be compared to the  $LCoE_{WH}$ s of future Solar Decathlon teams to determine whether DOE's long-range objectives are being met.

For this contest activity, teams are required to summarize their building energy optimization results and explain how the optimization results were used to inform design decisions. The Economic Analysis Jury does not expect teams to always choose the most economically appropriate designs and equipment. Sound economic decisions do not necessarily equate to sound competition decisions because of the peculiarities of the competition. Therefore, the calculation of an *accurate* LCoE<sub>WH</sub> is more important than the calculation of a *low* LCoE<sub>WH</sub>. Likewise, it is more important that teams use building energy optimization methods to recognize and identify the economic ramifications of available design and equipment options than it is for them to actually choose the most economical option.

Procedure for calculating inputs for the blue cells in the LCoE calculator:

1. Define a benchmark version of the marketable prototype house using the [Building America Analysis Spreadsheet](#). The definition of a “minimum physical” benchmark is more realistic and, therefore, preferable to, a benchmark defined exactly according to the outputs of the spreadsheet. A minimum physical benchmark, for example, would have R-13 walls instead R-11.7485 walls even if the spreadsheet suggests R-11.7485 walls because R-13 insulation is actually available on the market and R-11.7485 isn’t. Refer to the [Building America Research Benchmark](#) document for more information about the benchmark definition.
2. Use a reputable hourly simulation tool, such as DOE-2, Energy Plus, TRNSYS, or others, to project the gross annual electricity load of both the benchmark and marketable prototype (can be net positive or net negative) houses in Phoenix, Arizona, Washington, D.C. (use the Sterling, Virginia weather file if the Washington, D.C. weather file is unavailable), and a third location of the team’s choosing. If the economic analysis was optimized for a particular location, that location should be chosen for the third weather file. Download the [Building America House Performance Analysis Procedures](#) document for more information about modeling the Building America benchmark and the marketable prototype houses.
3. Estimate the first costs and operation and maintenance costs of all building components for the benchmark and marketable prototype houses that contribute to the difference in energy performance between the two houses (do not include the installed PV system costs; they are considered in the green cells in the LCoE calculator). The difference between the benchmark and marketable prototype costs are called the “incremental” costs. The approach used to generate the Marketable Prototype Cost Estimate should also be used for the benchmark house.
4. Enter the following inputs into the LCoE calculator:
  - Incremental cost of house components affecting energy performance [US dollars (US)]; includes installation, permitting, and other associated costs
  - Annual gross (utility-billed) electricity load of benchmark (kWh/yr)
  - Annual gross (utility-billed) electricity load of prototype (kWh/yr); does not include energy generated by the PV system
  - Annual electricity generated by the PV system (kWh/yr)
  - Annual incremental (i.e., marketable prototype minus benchmark) operation, maintenance, and equipment replacement cost of building components affecting energy performance that are not part of the PV system (USD/yr).
5. Record the LCoE<sub>WH</sub>, which is located in the “Marketable Prototype” box.

### *Assumptions, guidelines, and requirements for BIPV and EEM Economic Analyses*

- The benchmark and marketable prototype houses must be all-electric, grid-tied, and net-metered.
- Justify significant assumptions and simplifications
- If custom equipment is used in the marketable prototype, the cost should be based on the sum of the equipment components' parts, unless teams can justify and document a rationale for a lower cost after the equipment becomes commercialized.
- The energy simulation results used in the economic analysis must be consistent with results presented in the Energy Analysis Reports. Teams are encouraged to use and cross-reference the energy analysis results in the economic analysis.
- If the design has been optimized for one of the three modeled locations, indicate which location in the report. The Economic Analysis Jury will take this into consideration, when it evaluates the results at the other two locations.
- Use constant 2007 USD in the analysis
- Assume that the car is driven 50 miles per week and requires a 0.2-kWh charge per mile driven. As it evaluates the effect of energy production capacity on LCoE<sub>WH</sub>, the Jury will be mindful of the possibility that many teams oversized their energy production capacity (and storage) for competition purposes.
- The benchmark and marketable prototype computer models should reflect the expected house configuration in its final installed location. This may affect foundation, energy storage, and other parameters that are likely to change between the competition and the final installation.
- The following financial parameters are consistent with [DOE assumptions](#) and are fixed in the LCoE Calculator:
  - Analysis period: 30 years (Jan 1, 2007 through Dec 31, 2036)
  - Inflation rate: 2.5%
  - Real discount rate: 5.5%
  - Federal tax: 28%
  - State tax: varies by state (see LCoE calculator)
  - Debt: 100% of installed system cost and 100% of incremental cost of EEMs
  - Term: 30 years
  - Rate: 6%
  - Price of purchased electricity:
    - Phoenix, Arizona: \$0.078/kWh
    - Washington, D.C.: \$0.074/kWh
    - Third location specified by team: varies by state (see LCoE Calculator)
  - Property tax: None
  - Insurance: None
  - Depreciation: None
  - Financial incentives: None.

- The following PV system performance parameters are consistent with [DOE assumptions](#) and are fixed in the LCoE Calculator:
  - PV system derating factor (apply to the PV system simulation): 5%
  - PV system degradation: 1% per year.

## Format Requirements

- There are no restrictions on the software tools that can be used for this Contest Activity, but all tools should be clearly identified.
- One electronic copy (Microsoft Word document or Adobe PDF for reports and Microsoft Excel for cost estimate) of each deliverable must be uploaded to the appropriate team folder on the Solar Decathlon FTP site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/Team\\_Folders/](ftp://ftp.nrel.gov/pub/solar_decathlon/Team_Folders/)) or e-mailed directly to Mike Wassmer at [sdrules@nrel.gov](mailto:sdrules@nrel.gov) on the respective due date by 5 p.m. mountain time. Points will be deducted for lateness. Please contact Mike Wassmer at [sdrules@nrel.gov](mailto:sdrules@nrel.gov) as soon as possible, if the chosen cost estimating software cannot export to Microsoft Excel.
- The Preliminary Economic Analysis Report (due June 13, 2006) shall include BIPV and EEM Economic Analyses results and discussion as of June 13, 2006. The main body of the report may not exceed 15 single-sided pages, using a single-spaced 11-pt font. The pages must be 8.5 in. X 11 in. (or closest metric equivalent) and may include any embedded graphics that are appropriately placed in the body of the report. Appendix material (e.g., data sheets, simulation results, and screen captures) may be included, if desired. The appendix shall have the same format as the body of the report and may not exceed 15 pages.
- The Final Economic Analysis Report (due August 7, 2007) shall include final BIPV and EEM Economic Analyses results and discussion. It will be evaluated and scored by the Economic Analysis Jury. The main body of the report may not exceed 25 single-sided pages, using a single-spaced 11-pt font. The pages must be 8.5 in. X 11 in. (or closest metric equivalent) and may include any embedded graphics that are appropriately placed in the body of the report. Appendix material (e.g., data sheets, simulation results, and screen captures) may be included, if desired. The appendix shall have the same format as the body of the report and may not exceed 25 pages.
- Each version of the cost estimate should get more detailed as the design is developed, and the building is constructed. All cost estimates should reflect the marketable prototype version of the house, not the competition house. In some cases, the marketable prototype and competition house may be significantly different. The purpose of first Cost Estimate (due June 13, 2006) is to ensure that teams have begun estimating costs for the building presented in the Design Development Drawings and Specifications. The Organizers will verify that the data is organized according to the MasterFormat standard and that the software package being used to generate the estimate is appropriate and capable of exporting to Excel. The second Cost Estimate (due March 6, 2007), third Cost Estimate (due August 7, 2007), and fourth Cost Estimate (due January 9, 2008) are expected to be significantly more detailed than the first Cost Estimate, because they are due after the design has been completed and construction has begun. Each subsequent version of these cost estimates is a refinement of the previous one and should reflect changes that have occurred between the respective deadlines. Note that only the third Cost Estimate will be evaluated by the Economic Analysis Jury.

## Contest 4: Communications

### *Web Site (50 pts):*

#### Timeliness

See [Web Site Contest Activity Details](#) for deadlines.

#### Content

- Adherence to professional best practices for Web site content
- Audience-appropriate language and tone; average consumers make up the audience for the purposes of this Contest
- Originality, creativity, and interest
- Correct spelling and grammar
- Inclusion of content specified by the Organizers. See [Web Site Contest Activity Details](#) for more information
- Effective and appropriate use of team branding
- Limited use and tasteful integration of Team Sponsor information and adherence to [Regulation 3.2: Event-Sponsor Recognition](#).

#### Design and Architecture

- Adherence to professional best practices for graphics, photos, color, and typography
- Design is audience appropriate, visually engaging, and consistently branded; average consumers make up the audience for the purposes of this Contest
- Interactive and multimedia elements add value to the site and function correctly
- Speed of load time is appropriately balanced with valuable use of graphics, multimedia, and scripting
- Effective and appropriate use of team branding
- Limited use and tasteful integration of Team Sponsor logos and adherence to [Regulation 3.2: Event-Sponsor Recognition](#)
- Site architecture (organization) and navigation elements are simple, comprehensible, and represent the hierarchical organization of site content
- Graphical navigation elements are easy to use, consistent, and well integrated with content and design.

#### Coding

Adherence to guidelines and recommended best practices provided by the Organizers; see [Web Site Contest Activity Details](#) for more information.

### ***House Tours (50 pts):***

#### Timeliness

A schedule for House Tour judging will be provided. Teams' tours will be judged "as is" at scheduled times.

#### Content

- Audience-appropriate language and tone; average consumers make up the audience for the purposes of this Contest
- Originality, creativity, and interest
- Effective and appropriate use of team branding
- Limited use and tasteful integration of Team Sponsor logos and information. Teams must follow [Section 3.3: Sponsor Recognition on the National Mall](#) and [Regulation 3.2: Event-Sponsor Recognition](#)

#### Presentation

- Demeanor of tour guides toward the public
- Innovative approaches to engaging visitors waiting in long lines outside the houses
- Appropriateness, effectiveness, and originality of tour materials
- Minimization of throwaway materials.

<b>Contest Activity</b>	<b>Points Available</b>
Web Site	50
House Tours	50
<b>TOTAL</b>	<b>100</b>

## Web Site Contest Activity Details

The following details supplement and are organized according to the explanation of [Contest 4: Communications—Web Site](#). Team Web sites also must comply with [Regulation 3, Communications Materials](#).

### Timeliness

- June 13, 2006: Submit the URL of the team Web site via e-mail to [ruby\\_nahan@nrel.gov](mailto:ruby_nahan@nrel.gov) by 5 p.m. Mountain time on June 13, 2006.
- June 28, 2006: Organizers provide feedback to teams regarding required coding changes to team Web sites.
- August 8, 2006: All team Web sites must be linked from the main Solar Decathlon site ([www.solardecathlon.org](http://www.solardecathlon.org)). When a team Web site has met all coding requirements, a link will be established to that team site from the main Solar Decathlon Web site. Any team site that has not been linked to from the main Solar Decathlon site by August 8, 2006, will not be judged during the Competition in fall 2007.
- Fall 2007: The exact deadline for the completion of Web sites for judging during the Competition is dependent on the schedule for the Event, which will not be finalized until summer 2007. However, teams should plan to have their Web sites finalized before arriving at the Mall. They may continue to make changes and updates to their sites throughout the Event. All team Web sites linked from the Solar Decathlon site will be judged “as is” on the date that Web site judging begins. The date for Web site judging will be provided in 2007.

### Content

#### *June 13, 2006*

- Web site content must identify the Project as the Solar Decathlon and recognize all Event Sponsors according to [Regulation 3.2, Event-Sponsor Recognition](#).
- By this point in time, the site must consist of a minimum of five pages.

#### *Fall 2007*

- All sites will be judged on the criteria listed in [Contest 4: Communications—Web Site](#) as well as the additional criteria listed below.
- Web site content must identify the Project as being a Solar Decathlon Project and recognize all Event Sponsors according to [Regulation 3.2, Event-Sponsor Recognition](#).
- Web site content should be complete and comprehensive. No allowances will be made for exclusion of content to preserve a team’s competitive edge in the Competition.



- The site must contain considerably more content at the final deadline than it did at the June 13, 2006, deadline, and that content should reflect the current state of the Project. There will be no minimum or maximum page requirements.
- For the purposes of the Competition, average consumers make up the target audience for the site.
- The Web site should discuss the team's Solar Decathlon Project, the team's progress and accomplishments to date, and the team's plans for the Event and Competition, including, but not limited to:
  - Project history
  - Team organization
  - Project timeline and accomplishments
  - Overall Project budget and Project costs
  - Explanation of the house's design, including:
    - The solar energy and energy efficiency design strategies and technologies used in the house
    - The rationale for the use of those strategies and technologies
    - The influence of transport, Assembly, and Disassembly on the design.
  - Systems, materials, product selection, and retail costs (all donations and in-kind contributions must have an associated retail cost; indicate any changes in materials and product selection over time, and the rationale for those changes)
  - House transportation, Assembly, and Disassembly plan
  - Planned competitive strategies for the Competition and their rationale
  - The Web site's audience (average consumers) must be able to find the answers to the following questions:
    - What is the cost of the entire Project?
    - What is the cost of constructing the house?
    - What is the retail value of all contributions and in-kind contributions?
    - Who made those contributions?
    - What is the retail value of the house?



## Design and Architecture

- All sites will be judged on the criteria listed in [Contest 4: Communications—Web Site](#).
- Web site design must include the Solar Decathlon logo to properly identify the Project according to [Regulation 3.2, Event-Sponsor Recognition](#).




## Coding

- June 13, 2006, and fall 2007: All sites are required to meet the minimum coding standards, listed below, for both deadlines. Web development experts at the National Renewable Energy Laboratory (NREL) will evaluate each team Web site at both deadlines to ensure they meet all Web site coding requirements. From June 13 to June 28, 2006, team sites will be reviewed for compliance with coding requirements. Teams are required to correct all coding requirement deficiencies indicated by the Web development



team. When teams have met all coding requirements, a link will be established between the main Solar Decathlon Web site and the team Web sites. All coding requirements must be met and a link established by August 8, 2006. Team Web sites that are not linked from the main Solar Decathlon Web site will not be judged in fall 2007. Team Web sites will be judged on their compliance with the coding standards in fall 2007.

- The minimum coding standards were selected from standards that apply to all Web sites developed after summer 2003 for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) as well as from Section 508 of the Americans With Disabilities Act (ADA). Where applicable, links to relevant sections of the EERE Communications Standards Web site are provided as an explanation of the requirements with the icon . Where applicable, those standards that are part of Section 508 have also been noted with the symbol . For more information about Section 508, visit: <http://www.section508.gov/>.

### **Common Elements**

- A text or graphical link to Solar Decathlon's home page is provided on the home page in either the header or the footer.
- At a minimum, an e-mail contact to the Webmaster is provided as a graphical or text link on the home page of the site.
- Footers on both home and second-level pages link properly.
- Left or top navigation (or both), if used, link correctly; on and off states work correctly and can be skipped by screen readers.  
- Each page has a meaningful and unique <title> tag and uses EERE style. 






### **Page Layout**

- Pages must display correctly (e.g., no horizontal scrolling is necessary to view the full width of the page) in 1024 x 768 resolution. (The previous standard, 800 x 600 resolution, is also acceptable.)
- Page information conveyed with color is also available without color, and foreground and background colors provide sufficient contrast.  
- Every page contains a header consistent with its related pages and standards within a site.


### **Directories and Files**

- File names do not contain upper-case letters, spaces, or special characters (e.g., & or \$).
- All extraneous, nonlinked files have been deleted.









### **HTML Syntax**

- HTML syntax follows HTML 4.01 or higher transitional standards and has been validated by the [W3C Validator](#). 
- Row and column headings have been provided for all data tables.  
- Images do not flicker with a frequency of greater than 2 Hz or lower than 55 Hz.  

## Links

- All links work throughout the site.
- Colors for hypertext links are consistent throughout the site.
- Links are coded relatively within the site. 





## Scripts/Applets/Dynamic Pages (CGI, JavaScript, Java, etc.)

- Every script works correctly in the standard browser set.  
- Content produced by scripting languages is accessible or has an accessible alternative.  
- Pages requiring applets or plug-ins must provide a link to an accessible page where they can be downloaded.  
- If a timed response is required, the user can request more time to complete an operation.  
- Back button functionality is not impaired.





## Forms


- Forms include text labels that correspond with form controls and markup to associate the two.  

## Graphics




- All images are stored in a subdirectory named “images.”
- Graphics have meaningful "alt" tags. (Use empty alt tags for spacer gifs and other unimportant graphics.)  
- Alt descriptions are used with all client-side image maps.  

## Multimedia


- All
  - All multimedia files are stored in and referenced from a separate subdirectory.
  - Equivalent alternatives are provided for all multimedia.  
  - Pages requiring an applet or plug-in must provide a link to an accessible page where the applet or plug-in can be downloaded.  
- QuickTime VR
  - All QuickTime VRs scroll correctly.
  - All QuickTime hotspots will work and go to the correct location.
- Flash
  - Animation has been tested on a browser without a plug-in downloaded. (Ensure the download process flows smoothly and that the animation works when loaded.)

- Check all links within Flash animation. If the user exits Flash animation early, ensure that she will go to an appropriate page.
- Sound works correctly.
- If Flash is used as an introductory “splash” screen, there is an option provided to skip it.
- Provide an accessible equivalent to the Flash animation. 

### ***Documents for Downloading and Printing***

- PDFs
  - All PDFs are stored and referenced from a sub-directory labeled "pdfs."
  - References to PDFs within the HTML document use a consistent format and link scheme throughout the site (e.g., [PDF 54 KB](#)). 
  - Every page with a PDF link also includes a link to download Adobe Reader (<http://www.adobe.com/products/acrobat/readstep2.html>) with the text “[Download Adobe Reader](#).”  
- Native file formats
  - All documents are posted in approved native file formats. These are:
    - Microsoft Word (.doc), Excel (.xls), and PowerPoint (.ppt)
    - Corel WordPerfect (.wpd)
    - PC executable files (.exe) and archived files (.zip)
    - Macintosh archived files (.hqx, .bin, .sit, .sea)
  - Native file format documents are placed in a separate subdirectory, such as a "docs" subdirectory.
  - References to native files within the HTML document will use the following format and link scheme throughout the site: Title of Document ([Software 54 KB](#)). Examples:
    - The Value of Renewables ([MS Word 54 KB](#))
    - The Value of Renewables ([Excel 54 KB](#))
    - The Value of Renewables ([PowerPoint 54 KB](#))

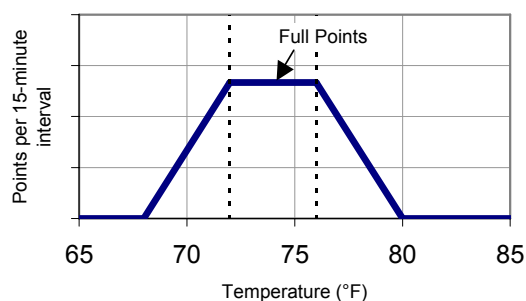
### ***Testing***

- For quality-control testing, test the site in the standard browser set: 
  - PC
    - Internet Explorer 6.0
    - Firefox 1.5
  - Mac
    - Safari 2.0

## Contest 5: Comfort Zone

### *Indoor Temperature Control (50 pts):*

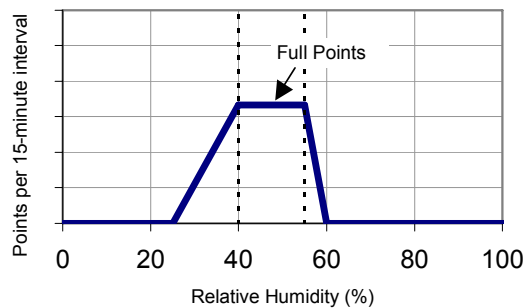
Teams earn the maximum number of points per scored 15-minute interval by keeping the time-averaged interior dry-bulb temperature between 72.0°F (22.2°C) and 76.0°F (24.4°C). A reduced point value is added to the team's score for every scored 15-minute interval that the time-averaged interior dry-bulb temperature is between 68.0°F (20.0°C) and 72.0°F (22.2°C) or between 76.0°F (24.4°C) and 80.0°F (26.7°C). Reduced point values are scaled linearly, as shown in the graph below. The number of points possible per 15-minute interval is not indicated on the y-axis of the graph. Teams can earn a total of 50 points for this Contest Activity, but the number of points per interval cannot be calculated until the total number of 15-minute intervals is known. Scoring will be suspended during hours that the houses will be open to the public for tours, so the total number of 15-minute intervals and the number of points per interval depend on the final event schedule.



Full Points:	72 °F ( 22 °C )	≤ Temperature ≤	76 °F ( 24 °C )
Reduced Points:	68 °F ( 20 °C )	< Temperature <	72 °F ( 22 °C )
or	76 °F ( 24 °C )	< Temperature <	80 °F ( 27 °C )
No Points:		Temperature ≤	68 °F ( 20 °C )
or		Temperature ≥	80 °F ( 27 °C )

### *Indoor Humidity Control (50 pts):*

Teams earn a maximum number of points per scored 15-minute interval by keeping the time-averaged interior relative humidity between 40.0% and 55.0%. A reduced point value is added to the team's score for every scored 15-minute interval the time-averaged interior relative humidity is between 25.0% and 40.0% or between 55.0% and 60.0%. Reduced point values are scaled linearly, as shown in the graph below. The number of points possible per 15-minute interval is not indicated on the y-axis of the graph. Teams can earn a total of 50 points for this Contest Activity. The total number of 15-minute intervals and the number of points per interval depend on the final event schedule.



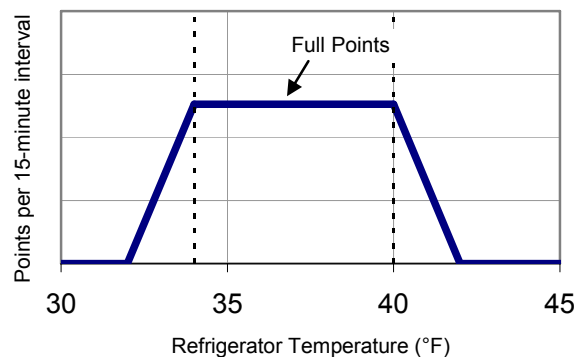
Full Points:	40 %	≤ Humidity	≤ 55 %
Reduced Points:	25 %	< Humidity	< 40 %
	or	55 %	< Humidity < 60 %
No Points:		Humidity	≤ 25 %
	or	Humidity	≥ 60 %

Contest Activity	Points Available
Indoor Temperature Control	50
Indoor Humidity Control	50
<b>TOTAL</b>	<b>100</b>

## Contest 6: Appliances

### *Refrigerator Temperature Control (15 pts):*

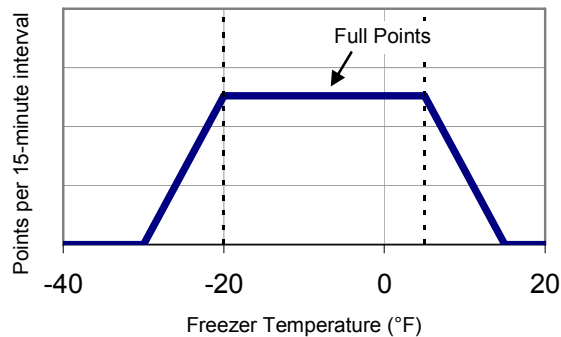
Teams earn a maximum number of points per scored 15-minute interval by keeping the time-averaged interior temperature of a [qualifying refrigerator](#) between 34.0°F (1.11 °C) and 40.0°F (4.44 °C). A reduced point value is added to the team's score for every scored 15-minute interval in which the time-averaged interior refrigerator temperature is between 32.0°F (0.00 °C) and 34.0°F (1.11 °C) or between 40.0°F (4.44 °C) and 42.0°F (5.56 °C). Reduced point values are scaled linearly, as shown in the graph below. The number of points possible per 15-minute interval is not indicated on the y-axis of the graph. Teams can earn a total of 15 points for this Contest Activity. The total number of 15-minute intervals and the number of points per interval depend on the final event schedule.



Full Points:	34 °F ( 1.1 °C )	≤	Temperature	≤	40 °F ( 4.4 °C )
Reduced Points:	32 °F ( 0.0 °C )	<	Temperature	<	34 °F ( 1.1 °C )
or	40 °F ( 4.4 °C )	<	Temperature	<	42 °F ( 5.6 °C )
No Points:			Temperature	≤	32 °F ( 0.0 °C )
or			Temperature	≥	42 °F ( 5.6 °C )

### *Freezer Temperature Control (15 pts):*

Teams earn a maximum number of points per scored 15-minute interval by keeping the time-averaged interior temperature of a [qualifying freezer](#) between -20.0°F (-28.9 °C) and 5.0°F (-15.0 °C). A reduced point value is added to the team's score for every scored 15-minute interval the time-averaged interior freezer temperature is between -30.0°F (-34.4 °C) and -20.0°F (-28.9 °C) or between 5.0°F (-15.0 °C) and 15.0°F (-9.44 °C). Reduced point values are scaled linearly, as shown in the graph below. The number of points possible per 15-minute interval is not indicated on the y-axis of the graph. Teams can earn a total of 15 points for this Contest Activity. The total number of 15-minute intervals and the number of points per interval depend on the final event schedule.



Full Points:	-20 °F ( -28.9 °C )	≤	Temperature	≤	5 °F ( -15.0 °C )
Reduced Points:	-30 °F ( -34.4 °C )	<	Temperature	<	-20 °F ( -28.9 °C )
or	5 °F ( -15.0 °C )	<	Temperature	<	15 °F ( -9.4 °C )
No Points:			Temperature	≤	-30 °F ( -34.4 °C )
or			Temperature	≥	15 °F ( -9.4 °C )

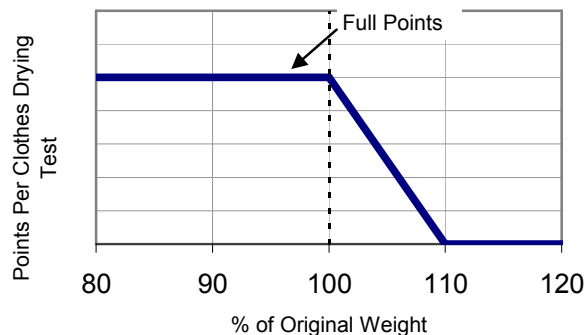
### ***Clothes Washing (10 pts):***

Teams may earn 5 points per day on 2 days of the Contest Week by washing 12 bath-size towels provided by the Organizers. A [qualifying clothes washer](#) must complete a normal factory-set, automatic cycle without intervention during the cycle. A temperature sensor placed in the clothes washer must reach 110°F (43.3°C) at some point during the cycle to earn the points. For combination washer/dryer machines, teams must have a reliable method for interrupting the machine between the wash and dry cycles so that the temperature sensor can be removed.

### ***Clothes Drying (20 pts):***

After performing the clothes washing tasks on 2 days of the Contest Week, teams may earn a maximum of 10 points per day by using an [approved drying method](#) to dry the 12 towels provided by the Organizers to a total weight less than or equal to the towels' total weight before washing. A reduced point value is added to the team's score if the "dry" towel weight is between 100.0% and 110.0% of the original towel weight. Reduced point values are scaled linearly, as shown in the graph below. A 6-hour time period will be defined, during which the towels must be collected, washed, dried, and returned. The drying method may include active drying (e.g., machine drying), passive drying, (e.g., on a clothes line), or any combination of active or passive drying. All drying methods that require the towels to be visible must be demonstrated to the Architecture and Market Viability Juries and as they tour the houses.





Full Points:		Weight	≤	100 %
Reduced Points:	100 %	<	Weight	< 110 %
No Points:		Weight	≥	110 %

### ***Dishwashing (10 pts):***

Teams may earn 2.5 points per day on 4 days of the Contest Week by running a [qualifying dishwasher](#) through a complete, approved, factory-set, automatic washing cycle without intervention during the cycle. A temperature sensor placed in the dishwasher must reach 125°F (51.7 °C) at some point during the cycle. Cycles including a “heated” or “power” dry will be disqualified.

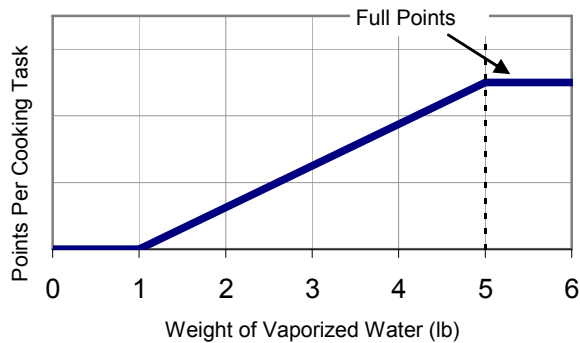
### ***Cooking (20 pts):***

Teams may earn a maximum of 5 points per day on 4 days of the Contest Week by successfully completing assigned cooking tasks. On 3 of those days, the cooking task involves the use of kitchen appliances to vaporize a prescribed weight of water. On the other day, the cooking task involves hosting a dinner party for neighboring houses.

### **Water Vaporization**

Teams may earn a maximum of 5 points per morning on 3 mornings of the Contest Week by using a kitchen appliance to vaporize 5.00 pounds of water in less than 3 hours. A reduced point value is added to the team’s score if between 1.00 and 5.00 pounds are vaporized. Reduced point values are scaled linearly, as shown in the graph below. Any kitchen appliance may be used, but it must operate in its normal configuration as it is vaporizing the water. Moving a microwave oven or portable hot plate from its intended location in the kitchen to a location near an open window or vent fan to reject heat is an example of an appliance not operating in its normal configuration. The Observer will weigh the container and water contents immediately before heating begins and immediately after the team indicates that it has completed vaporizing water and it is safe to place the container on the scale. The difference between the two weights is the official

vaporized water weight. Teams suspected of removing or dumping water from the container instead of vaporizing may be severely penalized.



Full Points:		Weight	≥	5 lb	
Reduced Points:	1 lb	<	Weight	<	5 lb
No Points:		Weight	≤	1 lb	

### Dinner Party

The village will be organized into five small “neighborhoods.” Each neighborhood will consist of four neighboring houses. Each evening between Monday and Thursday of Contest Week, one team in each neighborhood will host a dinner party for its neighbors. A different house in the neighborhood will host the dinner party each night. Therefore, by the end of Contest Week, every team in the village will have had a chance to host a dinner party. The dinner party order will be randomly selected prior to the teams’ arrival on the National Mall. The guest list for the dinner portion of the party must be limited to two people from each of the three invited teams. Teams will be required to prepare dinner for at least eight people – the six guests and two team members. Before and after the dinner portion of the party, the host team is permitted, but not required, to invite more people from the guest teams for hors d’oeuvres and/or nonalcoholic beverages. The duration of the dinner party is up to the host team, but it must begin after the completion of the afternoon shower test and conclude before 10 p.m. All food and beverage served to guests must meet the [food safety requirements](#) and the menu must be approved by the Organizers.

Each team will be required to evaluate each of their three neighbors’ dinner parties according to the following criteria:

- Quality of the meal
- Ambiance
- Overall experience.

Each team shall submit three anonymous scores between 0 and 5 to the Organizers by 8:00 a.m. on Friday morning of Contest Week. Non-integer scores are permitted. To maintain consistency among the subjectively judged Contest Activities, teams are encouraged to use the judging methodology described in the “Guidelines for Juries” section of the [Subjective Contest Activity Guidelines for Juries and Teams](#) supplemental document. Each team will receive three scores, which will be averaged to generate a final score for this Contest Activity.

### ***TV/Video Operation (5 pts):***

Teams may earn 1 point per day for 5 days of the Contest Week by showing a video on a [qualifying video display](#) continuously from 10 a.m. to 4 p.m. If the final day of Contest Week concludes prior to 4 p.m., the video must be shown until the conclusion of the continuously measured Contest Activities, such as Indoor Temperature Control.

*Note: Partial credit will be awarded for partially completing the task. For example, teams will earn 0.5 point for showing the video for at least 5 of the 6 required hours.*

### ***Computer Operation (5 pts):***

Teams may earn 1 point per day for 5 days of the Contest Week for operating their computer and [qualifying monitor](#) continuously from 9 a.m. to 5 p.m. The computer and monitor may enter low-energy mode at any time. If the final day of Contest Week concludes prior to 5 p.m., the video must be shown until the conclusion of the continuously measured Contest Activities, such as Indoor Temperature Control.

*Note: Partial credit will be awarded for partially completing the task. For example, teams will earn 0.5 point for operating the computer and monitor for at least 7 of the 8 required hours.*

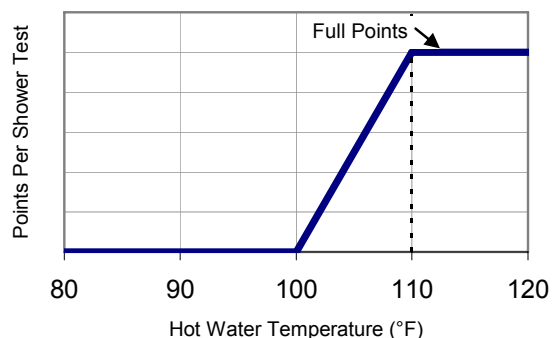
Contest Activity	Points Available
Refrigerator Temperature Control	15
Freezer Temperature Control	15
Clothes Washing	10
Clothes Drying	20
Dishwashing	10
Cooking	20
TV/Video Operation	5
Computer Operation	5
<b>TOTAL</b>	<b>100</b>

## Contest 7: Hot Water

### *Shower Tests (100 pts):*

Up to ten “shower tests” will be conducted during Contest Week. The normal schedule comprises one shower test in the morning and one shower test in the afternoon. However, if circumstances necessitate a deviation from the normal schedule, an attempt will be made to make up missed shower tests at a convenient time. This means that consecutive shower tests and/or days with more than two shower tests are possible. Teams should design and plan for this possibility. Consecutive shower tests are likely on the final day of Contest Week if the continuously measured Contest Activities, such as Indoor Temperature Control, are concluded early in the day. A deviation from the normal schedule will only occur if it applies to every team equally and fairly.

For each test, the team must deliver at least 15 gallons (U.S.) (56.8 liters) of hot water in no more than 10 minutes to qualify for points. Maximum points are earned by delivering an average temperature of at least 110°F (43.3 °C). An average temperature below 100°F (37.8 °C) earns no points. For temperatures between 100°F (37.8 °C) and 110°F (43.3 °C), the number of points is scaled linearly, as shown in the graph below.



Full Points:	Temperature ≥	110 °F	( 43.3 °C )
Reduced Points:	100 °F	( 37.8 °C ) < Temperature <	110 °F ( 43.3 °C )
No Points:	Temperature ≤	100 °F	( 37.8 °C )

Contest Activity	Points Available
Shower Tests	100
<b>TOTAL</b>	<b>100</b>

## Contest 8: Lighting

### *Electric Lighting Quality (50 pts):*

A Jury of lighting experts will evaluate the design and implementation of the house's interior and exterior electric lighting systems. The Jury will reward teams for:

- Identifying and responding to the specific client's lighting requirements
- Designing rich and varied lighted spaces that have adequate lighting for tasks and good color rendition
- Selecting attractive luminaires that properly distribute light
- Installing lighting controls that enhance the ease of operation, flexibility, and energy efficiency of the lighting system
- Designing exterior lighting systems that provide safety, security, and aesthetics for residents, guests, and passers-by.

A team's illuminance selections demonstrate its understanding of the particular space and the needs of the clients. The Jurors will rely mostly on their experience to evaluate a team's illuminance selections throughout the house. However, the Organizers will assist the Jurors by making horizontal illuminance measurements at several key locations and providing the results to the Jurors as the Jury enters each house for its tour. These objective measurements will help the Jurors calibrate their subjective evaluations of illuminance at these and other locations throughout the house. The table below summarizes the illuminance measurement locations.

<i>Room Location</i>	<i>Specific Measurement Location</i>	<i>Specific Task</i>	<i>Recommended Horizontal Illuminance* (footcandles)</i>
Kitchen	One measurement at center of sink at counter height	Cleaning and inspection of dishes, utensils, evaluation of color and texture of foods in preparation, reading, and measuring	50
Dining	One measurement at center of table top	Enhance the color and texture of the food while creating a festive mood and providing adequate light levels	5
Bathroom	One measurement at a point 61 inches above finished floor and 16 inches in front of center of mirror	Shaving and applying makeup	30

\* The source of these recommendations is the 9<sup>th</sup> Edition of the IESNA Lighting Handbook, which states, “the recommended illuminances provided in the Design Guide are based on Society’s judgment of best practice for ‘typical’ applications. Every situation is unique so, naturally, typical conditions may not be appropriate for a specific application. As a professional, the lighting designer should have a better understanding of the particular space and the needs of the occupants and clients than what can be presented in a recommended illuminance value for a typical space.” Therefore, teams are encouraged to establish their own appropriate illuminance targets throughout the house. However, if a team deviates by, say, 1/3 more or 1/3 less than an illuminance recommended by a reputable design guide, it should carefully document the justification for its deviation and justify the deviation to the Jury’s satisfaction.

### ***Daylighting Quality (25 pts):***

A Jury of lighting experts will evaluate each team’s ability to address the following important factors in its daylighting design and implementation:

- Human factors, including physiology, perception, preferences, and behavior
- Effects of daylight on all materials, including furniture, artwork, and plants
- Controlled admission of direct sunlight
- Controlled admission of diffuse daylight
- Integration of building systems, including the electric lighting, fenestration, interior geometry and finishes, manual and automatic control systems, and active climate control systems.

### ***Evening House Lighting (15 pts):***

This Contest Activity encourages teams to save energy by reducing the *total connected power* of the lighting system. (Note: In addition to its assessment of lighting quality, the Lighting Jury will also assess potential energy savings attributable to *lighting controls*. The lighting control evaluation is one of the Electric Lighting Quality Contest Activity criteria.)

The Contest Activity procedure follows:

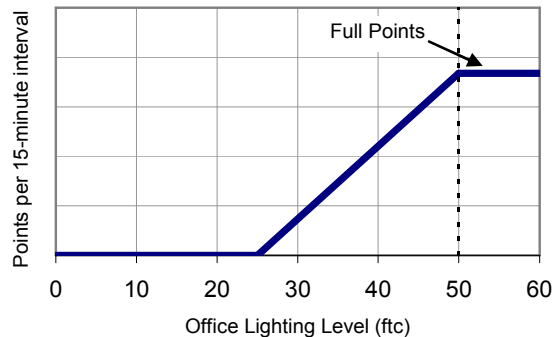
On each evening from Monday through Thursday of Contest Week, with the exception of the evening during which the team hosts a dinner party and the period of time during which the Lighting Jury is in the house, *all* interior and exterior house lights, with the exception of entry door lights on motion sensors, shall be on between 7:30 p.m. and 9:30 p.m. to receive the full 5 points. All dimmers shall be adjusted to their highest positions and all other lighting control equipment shall be disabled or overridden so that the controlled lamps are fully and continuously on during the 2-hour period.

Partial credit will be awarded for partial compliance. However, a team is only eligible for partial credit if it informs its assigned Observer when it is turning on or off selected lamps.

### ***Daytime Workstation Lighting (10 pts):***

Before the Contest Week begins, photometers (light level sensors) will be installed on the surface of the workstation desk. Light-emitting devices within 18 in. (45.7 cm) of the sensors are not permitted.

Teams earn the maximum number of points per 15-minute interval by keeping the time-averaged office work surface light level above 50 footcandles (538 lux) between 9 a.m. and 5 p.m. on 4 days of the Contest Week. A reduced point value is added to the team's score for every 15-minute interval the time-averaged office work surface light level is between 25.0 footcandles (269 lux) and 50.0 footcandles (538 lux). Reduced point values are scaled linearly, as shown in the following graph.

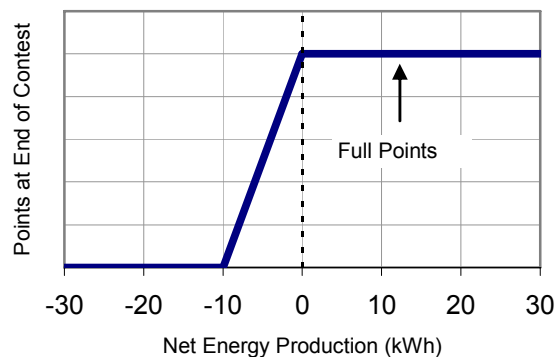


Full Points:		Light Level	$\geq$	50 ftc ( 538 lux )
Reduced Points:	25 ftc ( 269 lux )	<	Light Level	< 50 ftc ( 538 lux )
No Points:		Light Level	$\leq$	25 ftc ( 269 lux )

Contest Activity	Points Available
Electric Lighting Quality	50
Daylighting Quality	25
Evening House Lighting	15
Daytime Workstation Lighting	10
<b>TOTAL</b>	<b>100</b>

## Contest 9: Energy Balance

Teams whose houses have produced a net amount of electrical energy of 0.0 kWh or more over the course of the continuously measured portion of Contest Week will earn 100 points. Teams whose net electrical production is less than -10.0 kWh will receive 0 points. Teams whose net electrical production is less than 0.0 kWh but greater than -10.0 kWh will receive points that have been scaled linearly, as illustrated in the graph below.



Full Points:	Net Energy	$\geq$	0 kWh
Reduced Points:	-10 kWh < Net Energy	<	0 kWh
No Points:	Net Energy	$\leq$	-10 kWh

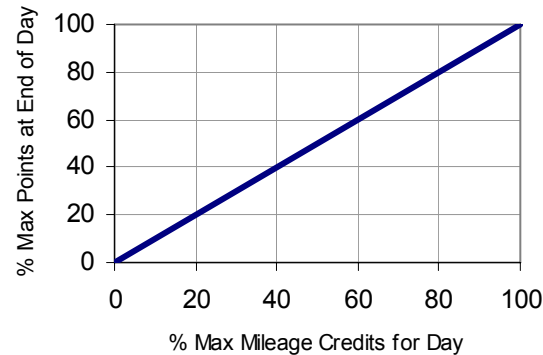
Contest Activity	Points Available
Energy Balance Measurement	100
<b>TOTAL</b>	<b>100</b>



## Contest 10: Getting Around

Points will be awarded on a daily basis for mileage credits earned according to the graph below and the associated table of points. The team that accumulates the most mileage credits on each day of the Contest Week establishes the maximum mileage credits and receives all available points for that day. The other teams receive a percentage of the daily available points; the points they receive are determined by, and equal to, the percentage that they have earned of the daily maximum mileage credits. For example, if team A accumulates 50 mileage credits on day 1 and team B accumulates 40 mileage credits on day 1, team A would earn 20 points and team B would earn 16 points for day 1. Each team can select its own driving route(s).

*Note: Circumstances necessitating a deviation from the expected Monday-Friday schedule will result in a redistribution of available points.*



Contest Activity	Points Available
Mileage Credit: Monday	20
Mileage Credit: Tuesday	20
Mileage Credit: Wednesday	20
Mileage Credit: Thursday	20
Mileage Credit: Friday	15
The Final Lap	5
<b>TOTAL</b>	<b>100</b>

# Solar Decathlon Building Code

## 1. Introduction

Although there is some degree of overlap between the two, it is important to note some crucial distinctions between the Competition Regulations and the Solar Decathlon Building Code. The Competition Regulations exist to promote a fair and interesting competition. The Solar Decathlon Building Code exists to protect the public health and ensure safety. Failure to comply with the Competition Regulations may result in official warnings, point penalties, or disqualification from the Competition. Failure to comply with the Solar Decathlon Building Code prohibits the participation of your house in any aspect of the overall Event. Therefore, compliance with the Solar Decathlon Building Code is a prerequisite for participation in the Competition.

## 2. Adopted Codes

The 2006 International Residential Code of the International Code Council and the 2005 National Electric Code of the National Fire Protection Agency have been adopted by reference as the Solar Decathlon Building Code and have the same force and effect as though fully set forth in the 2007 Solar Decathlon Rules and Regulations, except as specifically amended by provisions in the 2007 Solar Decathlon Rules and Regulations.

## 3. National Park Service Regulations

### 3.1 *Professional Engineer Stamp*

The National Park Service (NPS) requires that structural drawings and calculations are stamped by a Professional Engineer (P.E.) certifying that the structures are safe for the public to enter. Refer to Section 6 for structural design criteria.

### 3.2 *Public Tours*

#### 3.2.1. *Accessible Route and Means of Egress*

The public will have access to all the structures within the Solar Decathlon village at various times during the Event; therefore, all structures must meet the specific accessibility requirements in Section 5: Accessibility. Teams are required to provide an accessible route to all portions of the house and exterior that are available to the public during the tour. This does not mean that the entire house needs to be accessible.

The house shall be designed to meet the Means of Egress provisions in Section 4.2. These requirements supersede and replace those contained in IRC Section 311.

### *3.2.2. Handouts*

Teams are permitted to give one and only one informational brochure/handout to each member of the general public. No other handouts are permitted.

### *3.2.3. Sale of Items*

Teams are prohibited from selling items to the general public on the National Mall.

## **3.3 Sponsor Recognition on the National Mall**

The NPS has strict rules that will affect the way in which the Solar Decathlon teams and Organizers recognize Team and Event Sponsors. The Solar Decathlon Organizers also have developed rules that affect sponsor recognition. The Organizers reviewed the relevant NPS document regulating events on the National Mall in Washington, D.C., National Capital Field Area (NCFA) Requirements for Special Events Held on Parkland, as a starting point to develop the guidelines contained in this document. The Solar Decathlon Rules and Regulations Committee provided additional guidelines. The Organizers consult regularly with NPS regarding all plans for the Solar Decathlon, and the Rules and Regulations Committee meets regularly in an ongoing process of developing rules and regulations for the Project. Additional guidelines may be developed at a later date. The Organizers interpret NPS rules and regulations to the best of their abilities. They will attempt to get clear approval from NPS for plans for the Event at all times, but NPS has the final word in these matters. It is possible that despite this guidance, a team may be requested to remove items NPS does not consider appropriate for the Event.

Within certain restrictions, it is possible for teams to use their sponsors' logos in and on their Solar Decathlon houses. These restrictions apply but are not limited to all communications materials that will be on display or distributed at the Event on the National Mall. These restrictions apply to both the interior and exterior of your house. Any communications materials may be used only to identify the Solar Decathlon or a portion of the Solar Decathlon (e.g., communications materials related to one of the Contests). Sponsors may be recognized with text, logos, or both, but the text and logos must appear in conjunction with Solar Decathlon text and logo and may not be larger than one-third the size of the Solar Decathlon text and logo. The use of commercial notices or advertisements, models of commercial products, or structures representing commercial products is strictly forbidden.

To provide guidance, the Organizers have developed requirements for some communications materials the teams may be considering. These requirements apply to but are not limited to the materials listed in this document. All communications materials, except those

prepared specifically for and viewed only by the judges for other Contests (e.g. materials prepared for the architecture jury), will support the goal of Contest 4: Communications—to educate consumers about energy efficiency and solar energy. Communications products will be targeted to an average consumer audience and will exist for the purposes of describing and explaining each team’s house design, Construction, Assembly, functioning, and performance, including the solar energy and energy efficiency design strategies and technologies in the house, and each team’s process and experience in the Project.

### *3.3.1. Signs, Exhibits, Posters*

Signs, exhibits, and posters will exist only to support the goal of Contest 4 as described above. Signs, exhibits, and posters the Organizers determine do not support this goal, that exist largely for the recognition of sponsors, (or both) will be removed. All signs, exhibits, and posters should contain the Solar Decathlon logo or Solar Decathlon title text to clearly identify connection to the Event. If the content of signs, exhibits, and posters pertains to a specific component of the Event (e.g., one of the Contests), indicate to which component it pertains. Any text that refers to sponsors or any sponsor logos should not be greater than one-third the size of the Solar Decathlon title text, the text that identifies a specific component of the Event, or the Solar Decathlon logo. If sponsors are recognized through logos, the Solar Decathlon must be recognized using the Solar Decathlon logo. If text is used to recognize sponsors, either text or logo may be used to recognize the Solar Decathlon.

### *3.3.2. Plaques, Photos, and Wall Art*

Plaques, photos, and wall art will exist only to add aesthetic value to the house or to support the goal of Contest 4 as described above. Plaques, photos, or wall art that the Organizers determine do not add aesthetic value to the house, do not support this goal, exist largely for the recognition of sponsors, (or any combination of the three) will be removed. Any plaques, photos, or wall art that recognize sponsors should contain the Solar Decathlon logo or Solar Decathlon title text to clearly identify their connection to the Event. If the content of the plaques, photos, or wall art pertains to a specific component of the Event (e.g., any of the Contests), indicate to which component it pertains. Any text that refers to sponsors or any sponsor logos should not be greater than one-third the size of the Solar Decathlon title text, the text that identifies a specific component of the Event, or the Solar Decathlon logo. If sponsors are recognized through logos, the Solar Decathlon must be recognized using the Solar Decathlon logo. If text is used to recognize sponsors, either text or logo may be used to recognize the Solar Decathlon.

### *3.3.3. Furnishings*

Home furnishings (e.g., furniture, floor and window coverings, clocks, sculptures, knick knacks, figurines, and bookends) in the house will exist only to add aesthetic value. Any furnishings that are used to recognize sponsors will be removed.

#### *3.3.4. Appliances and Electronics*

"Off-the-shelf" appliances and electronics that feature a "built-in" manufacturer's logo are acceptable. Marketing and sales material will not be adhered or attached to appliances and electronics or distributed in any other way on the National Mall.

#### *3.3.5. Publicity Materials and Printed Materials for Distribution on the National Mall*

The teams' brochures, binder, or folder containing the Media/VIP kit, and any materials within the binder or folder (see Regulation 3.2: Event-Sponsor Recognition) should contain the Solar Decathlon logo or Solar Decathlon title text to clearly identify connection to the Event. If individual contents in the binder or folder pertain to specific components of the Event (e.g., one of the Contests), indicate to which component they pertain. Any text that refers to sponsors or any sponsor logos should not be greater than one-third the size of the Solar Decathlon title text, the text that identifies a specific component of the Solar Decathlon, or the Solar Decathlon logo. If sponsors are recognized through logos, the Solar Decathlon must be recognized using the Solar Decathlon logo. If text is used to recognize sponsors, either text or logo may be used to recognize the Solar Decathlon.

#### *3.3.6. Video/Audio/Electronic Presentations*

Video/audio/electronic presentations will exist only to support the goal of Contest 4 as described above. Video/audio/electronic presentations that the Organizers determine do not support this goal, exist largely for the recognition of sponsors, (or both) will be removed. All video/audio/electronic presentations should contain the Solar Decathlon logo or Solar Decathlon title text to clearly identify connection to the Event. If the content of video/audio/electronic presentations pertains to a specific component of the Event (e.g. any of the Contests), indicate to which component it pertains. Any text that refers to sponsors or any sponsor logos should not be greater than one-third the size of the Solar Decathlon title text, the Solar Decathlon logo, or the text that identifies a specific component of the Solar Decathlon. Audio scripts must be written and recorded such that their content supports the goal of Contest 4 and clearly identifies connection to the Solar Decathlon or a component of the Solar Decathlon (e.g., any of the Contests). No more than 20% of the total time, 1 minute, or whichever is less, of a video/audio/electronic presentation may be dedicated to recognition of sponsors. Television- or radio-style commercial advertising is prohibited. Video and audio loops, and screensavers that serve only to recognize sponsors are prohibited.

### **3.4 Food and Beverage**

Only NPS-approved vendors can provide food and beverage to the visiting public on the National Mall.

### **3.5        *Damage Liability***

Each team is financially responsible for any damage it causes to the National Mall.

### **3.6        *Construction Equipment***

On the grassy areas, teams will be permitted to use a forklift or similar small lifting equipment to aid in the Assembly and Disassembly of their houses. However, forklifts or other small vehicles used during Assembly and Disassembly may be driven on the grass portion of the National Mall only if these vehicles are driven on an NPS-approved product designed to protect the grass. Truck-mounted cranes, trailers, semi-trailer trucks, etc., are limited to the gravel paths and may not be driven on the grass at any time. Under special circumstances approved by NPS and the Site Operations team, trailers and semi-trailers may be driven on the NPS-approved product.

### **3.7        *Ground Penetration***

No digging will be permitted except for tie-downs needed to meet wind loading requirements. Large stakes or screws, similar to those used for circus tents, may be used to anchor the structures. Screws or stakes used with tie-downs are limited to an 18-in. (45.7-cm) vertical depth. The NPS does make an exception to the 18-in. rule for the installation of grounding means for the house's electrical system. At certain times during the Assembly phase, an NPS representative will be on site to identify an acceptable location near each house for the installation of grounding means.

### **3.8        *Impact on the Turf***

Low-impact footings and tie-downs must be used to support structures on the grass portion of the National Mall. Teams will not be permitted to build or place floors directly on the grass.

Teams will be required to support all water tanks to minimize damage to the National Mall turf.

### **3.9        *Driving***

Teams are permitted to drive the electric vehicles on National Mall turf to enable charging or parking within a carport or garage or area close to the team's house. When an electric vehicle enters or exits the National Mall, it must be "walked" (accompanied by a student Team Member on foot in front of the car). The electric car must be walked from the parking area, carport, or garage to the street and vice versa.

### **3.10      *Hydrogen Systems***

Teams are responsible for getting hydrogen systems approved by the Washington, D.C. (DCFD) fire department. Written approval from DCFD must be received by the NPS before final approval can be considered. Since hydrogen gas does not contain an identifiable odor, all enclosed spaces containing hydrogen gas lines, fueled equipment, and or storage vessels must be provided with hydrogen gas detectors and alarms.

### **3.11      *Spill Containment***

Generators must be equipped with secondary containment systems that can accommodate all of the oil, fuel, and coolant that the generator contains at maximum capacities. All drains for appliances or sinks need to be routed back to a 350-gallon (1325-liter) minimum capacity tank to ensure that wastewater is not dispersed onto the National Mall turf or into storm drains. All wastewater and water used in Contest 7: Hot Water must be stored in the wastewater tank. During the Event, dumping of water on the lot will not be permitted, according to NPS rules.

## **4.      *Building Planning and Construction***

The building is intended to be representative of a single-family dwelling constructed in accordance with the provisions contained in the International Residential Code (IRC). Because portions of the building will be open to viewing by the general public, specific provisions of the International Building Code (IBC) also apply.

### **4.1      *Fire Protection and Prevention***

#### **4.1.1.      *Fire Protection Plan***

Provide a fire protection plan. This plan should indicate the location of fire extinguishers, how egress will be made from the unit, and who will be responsible for life safety (the team's "Fire-Watch Captain") during the Event. Include a written operations plan for the fire-watch personnel. Successful demonstration of the plan will be required before any public tour of the building will be permitted.

#### **4.1.2.      *Required Equipment***

Each house will be required to have smoke alarms per IRC requirements and a fire extinguisher with a minimum Underwriters Laboratory (UL) rating of 2A-10BC. All battery system rooms or rooms containing a battery system enclosure must have a smoke detector that is either audible from outside the room or has a remote indicator that shall be monitored by the team. Smoke alarms shall be connected to the

AC voltage side of the inverter and provided with independent (with the alarm) battery backup. All alarms shall be interconnected and all shall sound when one is activated. (IRC, Sec. R313)

## **4.2        *Means of Egress***

The following means of egress components accessible to the public shall comply with Chapter 10 of the International Building Code.

### **4.2.1.        *Stairs***

Stair treads shall be a minimum of 11 in. (27.9 cm) deep with risers a maximum of 7 in. (17.8 cm) high for any portion of the stairs accessible to the public. Neither treads nor risers shall deviate more than 0.375 in. (0.95 cm) over the entire run of the stairs. "Demonstration stairs" may use 10-in. (25.4-cm) minimum treads and 7.75-in. (19.7-cm) maximum risers in accordance with IRC Section 311. "Demonstrator" spiral stairs shall comply with the IRC. Ladders or stairs with steeper geometries may be provided as "demonstrators" but the design team should be aware that United States building codes typically do not permit their use to habitable spaces. (IBC, Sec. 1009.3 and IRC, Sec. R311.5)

### **4.2.2.        *Handrails***

Handrails shall be provided on both sides of stairs or ramps used by the public during the display. All handrails shall be designed in accordance with IBC Chapter 10. (IBC, 1009.11)

## **4.3        *Interior Finishes***

Interior finishes must comply with IRC Section R315.

## **4.4        *Glazing***

The following hazardous locations are subject to human impact and require safety glazing (see IRC Section 308 for specific details and exceptions).

- Glazing in doors
- Glazing in doors, surrounds, and walls enclosing bathtubs or showers
- Glazing in windows within a 24-in. (61.0-cm) arc of either vertical edge of a door and less than 60 in. (152.4 cm) above the floor
- Glazing within 36 in. (91 cm) of stairways and/or within 60 in. (152.4 cm) of the bottom edge of stair treads when the bottom edge of the glazing is less than 60 in. (152.4 cm) above a walking surface



- Glazing in panels located with all the following conditions present:
  - Pane of glazing is greater than 9 ft<sup>2</sup> (0.836 m<sup>2</sup>)
  - Bottom edge of glazing is less than 18 in. (45.7 cm) above the floor
  - Top edge of glazing is greater than 36 in. (91.4 cm) above the floor
  - Walking surface is located within 36 in. (91.4 cm) of the glazing (IRC, Sec. 308.4).

#### **4.5      *Roofing***

Provide details on the proposed roofing system. All roofing materials shall comply with IRC Chapter 9.

#### **4.6      *Foam Plastic***

Foam plastics used for building construction shall only be permitted if the foam plastic is isolated from the interior of the building with 0.5-in. (1.27 cm) thick gypsum board. This applies to foams typically used in SIPS wall, floor, and roof systems. Provide documentation to demonstrate compliance (IRC, Sec. R314).

#### **4.7      *Exterior Envelope***

Provide section detail of proposed wall assembly showing framing, sheathing, water resistive barrier, flashing, and exterior cladding as applicable (IRC, Sec. R703).

#### **4.8      *Ceiling Height***

Ceiling height shall provide a minimum of 7 ft (213 cm) of headroom (IRC, Sec. R305).

#### **4.9      *Skylights***

IRC Section R308.6 regulates skylight glazing. Glazing is limited to certain types, and screening under the glazing may be required. Indicate which glazing products are to be used and provide sufficient details in the submitted plans to ensure compliance (IRC, Sec. 308.6).

## **5. Accessibility**

### **5.1 Accessible Route – Interior**

An accessible route shall be provided within the unit to all spaces accessible to the public. Other accessible features may be included in rooms such as kitchens and bathrooms at the discretion of the designers. If any of the features are intended for use by the public, they shall be accessible.

### **5.2 Accessibility – Habitable Roof Deck and Interior Second Floor/Loft Levels**

This building is intended to demonstrate a single-family dwelling that would not normally be regulated by any federal accessibility standard. However, the building is open to the public for educational purposes and must be accessible in all primary function areas. Therefore, any portion of the building where the public is permitted must be on an accessible route. The Americans with Disabilities Act (ADA) requires an elevator to be installed in buildings (funded pursuant to Title II) where an accessible route is required to stories above the first floor (such as the roof deck, second floor, or loft). The 3000-ft<sup>2</sup> exception located in IBC Section 1104.4 Exc. 1 is superseded by Federal regulation.

Following a discussion with a representative of the ADA Assistance Center, it appears acceptable to “demonstrate” a roof deck, loft, or upper level accessed via a stair, or other means of inaccessible access as long as no member of the public, organizers, or team competitors is allowed to access the space during the public display. Any provided means of access shall be fully gated or cordoned off to inhibit entry. Adherence to these guidelines should remove any perception that the upper level is being used as a primary function and therefore subject to the accessibility provisions of the ADA.

### **5.3 Accessibility – Ramps**

The following are the most important regulations regarding ramps.

- A “ramp” is any sloping surface used as part of the circulation path that has a slope in excess of 1:20.
- The slope of a ramp cannot exceed 1:12.
- 60-in. (152.4-cm) long landings are required at the top and bottom of the ramp
- A 60-in. (152.4-cm) by 60-in. landing is required at any point where a ramp changes directions.
- Handrails are required if the ramp’s rise exceeds 6 in. (15.2 cm) (American Disabilities Act Accessibility Guidelines [ADAAG], Sec. 4.8 and ANSI A117.1-2003 Section 405).

## **5.4        *Changes In Elevation***

All changes in elevation (including even minor changes in areas such as door thresholds) must be considered along an accessible route. Changes not exceeding 0.25 in. (0.635 cm) are acceptable. Elevation changes between 0.25 in. (0.635 cm) and 0.5 in. (1.27 cm) shall be beveled at a maximum of 1:2. Any higher change in elevation exceeding 0.50 in. (1.27 cm) shall be by a ramp with a maximum slope of 1:12 (ADAAG, Sec. 4.5.2).

## **5.5        *Doors and Door Approaches***

All doors shall comply with ADAAG Section 4.13 (ANSI A117.1-2003 Section 404). Doors that can be fixed in an open position may be accepted as part of the accessible route if 32-in. (81.3-cm) minimum clearance is provided through the door opening with the door secured in the fully open position.

# **6.        Structural**

The structural drawings and calculations included in the construction drawings and specifications set must be stamped by a licensed professional engineer (P.E.). Obtaining the P.E. stamp is the responsibility of the teams, not the Organizers. The Organizers will submit stamped structural drawings and calculations to the NPS for final approval. It is strongly recommended that teams involve a licensed structural engineer throughout the design process, because he or she could require structural design changes that could affect other aspects of the house. In addition to meeting applicable IRC requirements, special attention must be given to the structural design challenges unique to the Solar Decathlon. These challenges include, but are not limited to, the following:

- Increased live loads because of public access to houses
- Necessity for tie-downs because of the lack of a permanent foundation (tie-downs must not penetrate more than 18 in. (45.7 cm) into the National Mall topsoil)
- Use of low-impact footings to protect the National Mall grass
- Unique wind loading conditions because of roof-mounted solar systems
- Increased dead loads because of unusual mechanical and electrical equipment, such as batteries and water storage.

## **6.1        *Prescriptive Requirements***

Structural systems shall be designed in accordance with the appropriate prescriptive provisions of the IRC. See alternate materials provisions in Section 6.6. For structural framing, a one-line structural plan view drawing is required at a minimum. Successive plan sheets shall be provided and shall include foundation footings, floor framing, wall locations, and roof framing. All structural components shall be listed including sizes, species and grade, and repetitive spacing (on-center distances). Include details on connections between joists and

beams, floor systems and foundations, walls and floors, rafters and beams, etc. Specify proprietary hangers or other mechanical connections. (IRC, Sec.R301.1)

## **6.2        *Design Loads***

The following minimum loads must be used in the structural design:

- Wind: 60 mph (26.8 m/s) (3-second gust), exposure category C (if tie-downs are not used, you must show that there is no overturning or uplifting with a safety factor of 2)
- Railings: 200-lb (890-N) concentrated load applied in any direction at any point at the top of the rail
- Interior Floor, Decks, Ramps: 50 psf (2.39 kPa) live load
- Roof: 20-psf (0.958-kPa) live load
- Soil: 1500-psf (71.8-kPa) load-bearing pressure on top of the soil
- Additional structural design requirements at the post-Event house location (to be determined by the engineer of record).

Structural plans shall indicate the design loads (e.g., 50 psf [2.39 kPa] floors, 100 psf [4.78 kPa] means of egress components, 20 psf [0.958 kPa] snow roof live load) and the location, size, and weight of special loads such as liquid storage tanks, mass or trombe walls, and battery storage racks (IRC, Sec. R310.2).

## **6.3        *Exterior Construction***

Structural plans shall include design details for any exterior appurtenances such as decks, stairs, ramps, awnings, canopies, and roof projections (IRC, Sec. R301.1).

## **6.4        *Specific Point Loads***

Provide wind-analysis calculations for point-load connections demonstrating the components' abilities to withstand 60-mph (26.8-m/s), exposure category C wind conditions. Provide point-load connection details for all solar panel connections to demonstrate that the connections will resist uplift (IRC, Sec. R301.1).

## **6.5        *Foundation Details***

Provide a foundation plan for temporary set up on the National Mall. Plans shall include location and size of all pad footings and required tie-down anchors (e.g., type, number, and installation configuration) to prevent wind uplift or over-turning (IRC, Sec. R401.1 and

R401.2). Please provide consideration for sloping or variable site conditions. The surface of each assigned site on the Mall may vary up to 18 in. (46 cm.) depending upon location.

## **6.6         *Alternate Materials***

Alternate materials are permitted as follows.

- Engineered Lumber (e.g., TJI's, LPI's, and BCI's) pursuant to specific manufacturer's design data. The product selected must carry a current International Code Council (ICC) Evaluation Services report. See <http://www.icc-es.org/>.
- Structurally insulated panel systems (SIPS) pursuant to specific manufacturer's design data. The product selected must carry a current ICC Evaluation Services report. Also be advised that foam plastics must be thermally isolated from the interior of the dwelling (see Section 4.6 for more details).
- Engineered trusses (floor or roof) must be designed in accordance with IRC Sections R502.11 or R802.10 as appropriate. Individual truss reports shall be provided for review and shall bear the seal of a registered design professional (IRC, R104.11).
- Other alternate materials may be permitted if approved pursuant to IRC Section 104.11. It is the responsibility of the applicant to provide adequate proof to document the alternate as meeting the intent of the prescriptive code requirements. The Organizers reserve the right to deny any alternate for failure to clearly demonstrate code equivalence.

## **6.7         *Structural Steel***

Provide structural details for load-carrying structural steel assemblies. Include welded or bolted connections within the assembly and where attached to other structures (IRC, R301.1.3).

# **7.         Electrical**

## **7.1         *General Requirements***

The provisions of the 2005 National Electrical Code will supersede the limited prescriptive electrical requirements contained in Chapters 33-42 of the 2006 International Residential Code.

All houses must meet all applicable electrical requirements stated in the 2005 National Electric Code (NEC2005). Particular attention should be paid to Articles 690, 480, 445, 250, 310, 400, and 240, which refer to photovoltaic system design, storage batteries, generators, grounding, conductors for general wiring, flexible cords and cables, and over-current protection devices, respectively. Teams are also encouraged to follow the guidelines in the following publication: Wiles, John C. (2006). *Photovoltaic Power Systems and the 2005*

## **7.2        *Drawing Requirements***

The following requirements are in addition to the requirements listed in the “Drawings and Specifications Contest Activity Details” document under the “Electrical” bullet:

- Electrical plan(s) must include layouts of proposed receptacles, switches, light fixtures, smoke alarms, ceiling fans, etc.
- Provide details on the proposed PV system along with a key for symbols used in the drawings. Such details shall include information on the photovoltaic panels, distribution (e.g., wiring, inverters, switch gear, and over-current protection), and storage equipment. (IRC, Sec. R106.1.1).

## **7.3        *Outdoor Receptacles***

Any receptacles used on the exterior of the building must be ground-fault circuit-interrupter (GFCI) protected. Enclosures provided must be suitable for damp locations. (IRC, Sec. E3802.3)

## **7.4        *Arc-Fault Circuit Protection***

Any AC circuit providing power to bedrooms shall be protected with arc-fault circuit protection (IRC, Sec. E3802.12).

## **7.5        *Ground-Fault Circuit Protection***

Any AC receptacles located in kitchens or bathrooms shall be GFCI protected (IRC, Sec. 3802.1 and 3802.6).

## **7.6        *Equipment Listings***

All equipment shall carry an approved testing agency's listing. Provide manufacturer's listing information for the PV equipment selected. (IRC, Sec. E3303.3)

## **7.7      *Battery Enclosure Separation***

All battery compartments shall be provided with the equivalent of 5/8-in.(1.59 cm) Type X gypsum board placed on the interior of the compartment on all walls and floors common to the interior of the building. Any penetrations into the interior of the building shall be sealed to resist the passage of smoke, flame, and hot gasses with approved materials.

Battery compartments containing more than 100 gallons (379 liters) total liquid electrolyte capacity shall be separated from the remainder of the building by a 2-hour fire barrier constructed in accordance with Section 706 of the 2006 International Building Code. Openings and penetrations in the fire barrier shall be protected as required by Sections 706.7 and 706.8 respectively.

## **7.8      *Battery Enclosure Ventilation***

All battery enclosures shall be provided with either passive or active ventilation. A battery cabinet placed in an equipment room must meet the same ventilation requirements as the room in which the cabinet is placed. The only difference is that, for a battery cabinet in an equipment room, the intake is typically the equipment room air; for a battery rack in an equipment room, the intake is typically the outside air. This distinction also applies to exhaust air locations. The following ventilation requirements apply to all battery types.

### **PASSIVE VENTILATION REQUIREMENTS:**

Passive ventilation shall consist of a lower gravity vent and an upper gravity vent.

The top of the lower gravity vent shall be located no more than 12 in. (30.5 cm) from the lowest point of the battery enclosure. The vent shall be unobstructed to allow fresh air intake into the enclosure and shall be sized to provide a minimum of 28 in.<sup>2</sup> (181 cm<sup>2</sup>) of net free ventilating area.

The upper vent shall be located in either the battery enclosure ceiling or in a battery enclosure sidewall. A ceiling vent shall be located at the highest point of the battery enclosure ceiling. The top of a sidewall vent shall be coincident with highest point of the battery enclosure ceiling. The vent shall discharge at least 5 ft (1.52 m) away from sources of air intake into the building and shall be sized to provide a minimum of 28 in.<sup>2</sup> (181 cm<sup>2</sup>) of net-free ventilating area. If the upper vent is ducted outside, the duct must be level or sloped upward from the battery room to the outside. These requirements prevent the accumulation of hydrogen gas near the ceiling of a battery enclosure.

### **ACTIVE VENTILATION REQUIREMENTS:**

Active ventilation shall consist of a lower fan-powered vent and an upper gravity vent.

Active ventilation shall be powered by a continuously operating, DC brushless fan. The fan shall provide a minimum of 1 cfm (0.47 L/s) of air supply for each square foot of floor area in the battery enclosure. The fan shall be oriented to generate a positive pressure in the battery compartment. The top of the fan inlet shall be located no more than 12 in. (30.5 cm) from the lowest point of the battery enclosure.

The upper vent shall be located in either the battery enclosure ceiling or in a battery enclosure sidewall. A ceiling vent shall be located at the highest point of the battery enclosure ceiling. The top of a sidewall vent shall be coincident with the highest point of the battery enclosure ceiling. The vent shall discharge at least 5 ft (1.52 m) away from sources of air intake into the building and shall be sized to provide a minimum of 28 in.<sup>2</sup> (181 cm<sup>2</sup>) of net-free ventilating area. If the upper vent is ducted outside, the duct must be level or sloped upward from the battery room to the outside. These requirements prevent the accumulation of hydrogen gas near the ceiling of a battery enclosure.

## **7.9        *Batteries***

For regular lead acid systems with greater than 50 gallons of electrolyte, refer to IFC 608.4 Spill Control and Neutralization, which states, “An approved method and materials for the control and neutralization of a spill of electrolyte shall be provided. The method and materials shall be capable of controlling and neutralizing a spill from the largest lead-acid battery to a pH between 7.0 and 9.0.”

For VRLA Systems of 50 gallons or more, refer to IFC 609.5 Neutralization, which states, “An approved manual method and materials for the neutralization of a release of electrolyte shall be provided. The method and materials shall be capable of controlling and neutralizing a release of 3 percent of the capacity of the largest VRLA cell or block in the room to a pH between 7.0 and 9.0.”

Refer to the “Battery Requirements and Guidelines” supplemental document.

## **7.10       *Photovoltaics***

Particular attention should be paid to Articles 690, 480, 445, 250, 310, 400, and 240 of the 2005 NEC, which refer to photovoltaic system design, storage batteries, generators, grounding, conductors for general wiring, flexible cords and cables, and overcurrent protection devices, respectively. Teams are also encouraged to follow the guidelines in the following publication: Wiles, John C. (2006). *Photovoltaic Power Systems and the 2005 National Electric Code: Suggested Practices*, Sandia Report SAND2005-0342-N. This publication can be downloaded for free at <http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html>.



## **8. Mechanical**

### **8.1 *Drawing Requirements***

Provide a key for symbols used in the drawings (IRC, Sec. R106.1.1).

### **8.2 *Return Air***

Return air shall not be taken from a bathroom, kitchen, mechanical, or furnace room. Return air shall not be taken where there is a presence of flammable vapors (e.g., battery storage room) (IRC, Sec. M1602.2, Items 2 and 4).

### **8.3 *Outside Air***

#### **8.3.1. *Intake Location***

Outside air shall not be taken closer than 10 ft (304.8 cm) from an appliance or plumbing vent, or discharge outlet of an exhaust fan (unless the intake is located at least 3 ft [91.4 cm] below the vent or fan discharge) (IRC, Sec. M1602.2, Item 1).

#### **8.3.2. *Screens***

Outside air inlets shall be provided with a screen with openings 0.25 in. (0.64 cm) to 0.5 in. (1.27 cm) (IRC, Sec. M1602.3).

### **8.4 *Bathroom Ventilation***

Bathrooms shall be provided with mechanical ventilation systems capable of providing 50 cfm (23.6 L/s) for intermittent ventilation or 20 cfm (9.4 L/s) for continuous ventilation, or provide windows allowing 1.5 ft<sup>2</sup> (0.139 m<sup>2</sup>) opening for natural ventilation (IRC, Sec. R303.3).

## **9. Solar Mechanical**

### **9.1 *Drawing Requirements***

Provide plan details for any proposed solar mechanical systems. Provide details on collectors, fluid distribution, heat exchangers, etc. along with a key for symbols used in the drawings (IRC, Sec. 106.1.1).

## **9.2        *Cross Connection***

Provide details for the solar hot water system. Provide details indicating if potable water or other heat transfer liquids will be employed. If other than potable water is used, an approved heat exchanger shall be employed to isolate potable water from transfer fluids (IRC Section R106.1.1).

## **9.3        *Access***

Solar collectors, controls, dampers, fans, and pumps shall be accessible for inspection, maintenance, repair, and replacement. (IRC, Sec. M2301.2.1).

## **9.4        *Roof Mounted Collectors***

The roof shall be constructed to support all loads imposed by the collectors. If collectors are intended to serve as the roof covering, documentation shall be provided to determine compliance with the roofing provisions in IRC, Chapter 9. If the collectors will be placed over the roof covering, the collectors and supporting structure shall be constructed of noncombustible material or fire-retardant-treated wood equivalent to that required for the roof covering (IRC, Sec. M2301.2.2).

## **9.5        *Pressure and Temperature Relief***

Pressure- and temperature-relief valves shall be provided for components under pressure. Relief devices shall be installed in sections of the system so that a section cannot be valved off or isolated from a relief device (IRC, Sec. M2301.2.3).

## **9.6        *Vacuum Relief***

A vacuum relief valve shall protect system components that might be subjected to pressure drops below atmospheric pressure during operation or shutdown. Plans shall indicate if this system is subject to vacuum conditions (IRC, Sec. M2301.2.4).

## **9.7        *Expansion Tanks***

Expansion tanks in solar systems shall be installed in accordance with IRC, Section M2003 in closed-fluid loops that contain heat transfer fluid (IRC, Sec. M2301.2.6).

## **9.8        *Solar Loop Isolation***

Valves shall be installed to allow the solar collectors to be isolated from the remainder of the system (IRC, Sec. M2301.2.8).

## **9.9        *Maximum Temperature Limitation***

Systems shall be equipped with means to limit the maximum water temperature of the system fluid entering or exchanging heat with any pressurized vessel inside the dwelling to 180°F (82°C). This protection is required in addition to required temperature and pressure relief valves in IRC, Section M2301.2.3. (IRC, Sec. M2301.2.9.).

## **9.10       *Collector and Thermal Storage Unit Labeling***

Collectors and storage units shall be listed and labeled to show the manufacturer's name, model number, serial number, collector weight, collector maximum allowable temperatures and pressures, and the type of heat transfer fluids that are compatible with the collector and storage units. (IRC, Sec. 2301.3)

## **9.11       *Prohibited Heat Transfer Media***

Flammable gasses and liquids shall not be used as heat transfer fluids (IRC, Sec. M2301.4).

## **9.12       *Backflow Prevention***

All connections from the potable water supply to solar systems shall comply with IRC, Section P2902.4.5 (IRC, Sec.M2301.5).

# **10.    Plumbing**

## **10.1       *Drawing Requirements***

The following requirements are in addition to the requirements listed in the “Drawings and Specifications Contest Activity Details” document under the “Mechanical and Plumbing” bullet.

- Provide a labeled isometric diagram of the proposed plumbing system for review. Clearly indicate waste lines, vent lines, potable water supply, heat exchange equipment, and the type of any heat exchange fluid other than potable water.
- Provide a key for symbols used in the drawings (IRC, Sec. 106.1.1).

## **10.2      *Water Closet Demonstration***

Water closets (W.C.) are installed for demonstration only and shall not be connected to any portion of the gray water disposal system. The W.C. shall be attached to a PVC or ABS 4-in. (10.2-cm) to 3-in. (7.62-cm) water-closet flange provided with a capped end. The cap shall be located as close as possible to the flange fitting. No structural member shall be cut or otherwise damaged to accommodate the W.C. flange assembly.

## **10.3      *Plumbing Wall – Structural***

Recommendation: Create a dedicated plumbing wall with thickness sufficient to allow pipe penetrations within the studs not exceeding 60% of the stud width in nonbearing walls (IRC, Sec. 602.6).

## **10.4      *Shower Mixing Valves***

Shower mixing valves shall be pressure balanced, thermostatic mixing, or a combination of the two, with the high limit set at 120°F (48.9°C) to prevent scalding (IRC, Sec. P2802.3 and P2708.3).

## **10.5      *Backflow Prevention***

Backflow prevention is required to isolate the potable water supply from the solar systems. See IRC Section P2902.2 for permissible devices. Because this project uses supply tanks for potable water, the use of a separate and isolated fill system for the solar component may be deemed acceptable backflow prevention (IRC, Sec. P2902.2).

## **10.6      *Supply***

No additives of any kind may be added to the water in the team's supply tank. This water is not for consumption at any time. Teams will be required to provide the tank and support this tank so that it does not damage the National Mall turf.

## **10.7      *Waste***

All substances used in combination with water to clean the house, dishes, utensils, etc., must be nontoxic and preferably biodegradable. Teams could incur a point penalty for any toxic substances that are found in the wastewater tank.

## **10.8      *Rainwater Collection***

Rainwater collection system design and installation must be approved and stamped by a public health official. Because of Department of Public Health rules and concerns, unapproved rainwater collection systems will not be allowed. The public health official's statement of approval must clearly indicate which applications are approved for the particular system.

## **11.      **Material Safety****

### **11.1      *Thermal Storage***

All thermal storage devices ("mass") must be made of stable, nontoxic materials. Material Safety Data Sheets (MSDS) must be submitted for all heat transfer fluids for approval. All liquid-based thermal storage systems must be marked with the NFPA's Hazard Warning Diamond appropriate to the technology.

### **11.2      *Paint Disposal***

Teams are not permitted to dispose of paint on the National Mall. Teams may either take unused paint home or find a local facility that disposes of or recycles paint.

### **11.3      *MSDS***

Material Safety Data Sheets (MSDS) are required for all materials to be used at the Event that require an MSDS, such as cleaning solvents, glycol, rubber cement, rubbing alcohol, etc.

## **12.      **Moveable Features****

Teams planning to move or transform major components of their houses outside of the Assembly and Disassembly phases are required to obtain special approval from the Organizers' Primary Safety Officer. Moving rooms, moving walls, changeable façades, collapsible spaces, and folding beds are some possible design features meeting this description. This message does not apply to smaller, more typical house features that may be reconfigured such as awnings, operable windows and window coverings, and doors. Qualifying features only include larger, more unusual, and potentially more dangerous features. The following rules apply to qualifying features.

- After the houses are assembled on the Mall, we will inspect every house and inform each team whether it has any qualifying features.

- If you would like us to try to determine before the Event whether your house has any qualifying features, please contact [sdrules@nrel.gov](mailto:sdrules@nrel.gov) to inquire.
- Although we cannot thoroughly evaluate the safety of a particular house feature until we see it operating, we will try to tell you with a reasonable degree of confidence whether certain features are subject to these rules.
- Qualifying features shall not be reconfigured during impound.
- Qualifying features shall not be reconfigured during public tours unless approved by the Organizers' Primary Safety Officer. To receive approval, a team must submit a safety plan describing how it will ensure safety during the movement of qualifying features, it must demonstrate the successful execution of the safety plan at some point before public tours begin, and it must continue to demonstrate the successful execution of the safety plan during public tour periods. If, at any time, the Primary Safety Officer witnesses unsafe conditions, he or she may prohibit the movement of qualifying features during public tours for the duration of the event."

## Brief Contest Reports

Teams have the option of submitting a brief report for each of the following subjective Contest Activities:

- Architecture Design and Implementation
- Engineering Design and Implementation
- Market Appeal
- Web Site
- House Tours
- Electric Lighting and Daylighting Quality (combine into one report).

Before the Event begins, reports will be given to the Jury associated with each of the Contest Activities listed above. The Jurors will use the reports to get a preview of what they will be evaluating at the Event. The Organizers also may use the contents of these reports in Solar Decathlon communications materials.

If a team chooses to submit one or more of the reports, each report must meet the following requirements.

- The length, including all text, figures, tables, and equations, may be no more than the front and back sides of a single sheet of paper.
- The body text and captions must be in 11 pt. (or larger) font size.
- One electronic copy (Microsoft Word document or Adobe PDF) of each report must be uploaded to the appropriate team folder on the Solar Decathlon FTP site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/Team\\_Folders/](ftp://ftp.nrel.gov/pub/solar_decathlon/Team_Folders/)) or submitted to Mike Wassmer at [michael\\_wassmer@nrel.gov](mailto:michael_wassmer@nrel.gov) on or before August 7, 2007. To be considered “on time,” the reports must arrive at their intended destination by 5 p.m. (Mountain time) on the due date. Late reports will have the number of days late noted on them before they are given to the Juries.

# Suggestions for Making Your Team's Solar Decathlon Web Site a Winner

## Brainstorm and Think!

Who are your target audiences (users)? Although the contest requirements stipulate a consumer audience, you may want to design your Web site for more than just that audience.

- What do you want to accomplish? Yes, your Web site is part of a contest, but you may have goals in mind other than just winning the contest (e.g., attracting sponsors).
- What is your team's mission? What is its "brand?" What are your key messages? All of these ideas should be integrated into your content and be evident to the user—we're not talking about a boring bulleted list, here!
- What images and content will compel users to visit your site? Look at other Web sites for design and content ideas. Pick out samples that impress you with their content, navigation, and appealing design.
- What's the best way to organize site content? Remember, your site will change over time. Content will expand. Goals for the site may change. Think ahead and design your site so that it doesn't have to be redesigned later.

## Design for Usability

- Usability is the "total user experience" and involves all the components of a Web site: content, information architecture (content organization), and design.
- When you design and develop your Web site, you must remember that **you do not represent your users—their needs may be different than you think**. A Web site that has good usability is designed and developed with the user in mind. Here are some things to keep in mind as you design your Web site:
  - o Focus on the users' needs, tasks, and goals.
  - o Spend time on initial research and requirements—scope out the project (clearly define audiences, look at other sites for inspiration, get educated about Web site development).
  - o Emphasis should be on the iterative design process—research, scope, develop concept, test, revise, test, revise—a lot of this can be done on paper before you actually code anything.
- Take a look at these specific Web site usability resources recommended by the famous Web guru, Jakob Nielsen before you get started:
  - o <http://www.useit.com/jakob/webusability/>
  - o <http://www.useit.com/homepageusability/>
  - o <http://www.useit.com/books/>



## Repeat Daily, “Content is King”

- Fancy design, flashy Flash, groovy animation, and other Web site bells and whistles do not compensate for poor content
- Take a look at these specific Web development and Web writing sites before you get started:
  - The U.S. Department of Energy’s (DOE) Office of Energy Efficiency and Renewable Energy’s (EERE) Web writing guidelines: <http://www.eere.energy.gov/communicationstandards/web/writing.html>
  - *Sun Microsystems* Web writing guidelines: <http://www.sun.com/980713/webwriting/>
  - An online Web style guide: <http://www.webstyleguide.com/>
  - Jakob Nielsen’s Web site: <http://www.useit.com/papers/webwriting/>

## Be Original

- Write original content. It is okay to adapt material from other sources. But rewrite that material into your own words, so it is specifically focused on your Solar Decathlon project.
- Do not, under any circumstances, plagiarize. Do not cut and paste large slabs of text from another Web site or other published source. Plagiarism is usually very obvious to the user. Don’t gamble that the judges will miss it.
- Make sure you have not violated any copyrights. At the least, get written permission to use content from another Web site or other published source. Cite the source of that information on your Web site. Your school may have specific rules about using copyrighted material. You should find out what those rules are and follow them. Look at EERE’s information about copyright: <http://www.eere.energy.gov/communicationstandards/web/copyright.html>
- Create an original look. Don’t use just the generic ideas, images, colors, backgrounds, and fonts from some “Web-site-from-a-box” development software.

## Make it Work for the Web

- Read EERE’s tips for organizing, writing, and labeling your Web site content; notice how the tip pages follow the guidelines presented <http://www.eere.energy.gov/communicationstandards/web/writing.html>
- Make each page autonomous. In other words, don’t assume that the reader has read all the other pages of your Web site and will, therefore, understand a fleeting reference to a bit of information from another page. You can add hyperlinks to facilitate a user’s understanding of content.

- Optimization: Remember that your site will be indexed in search engines such as Google, Yahoo, and MSN Search. Follow EERE's online writing tips so your HTML pages will have good titles and summaries in search results. If your site includes PDFs or native file formats such as Microsoft Word, Excel, and PowerPoint, follow EERE's standards and recommended practices so these files will also have good titles and summaries in searches. Search engines are disregarding meta tags, so concentrate on writing good content instead of writing meta tags that describe your content.  
<http://www.eere.energy.gov/communicationstandards/web/writing.html>  
<http://www.eere.energy.gov/communicationstandards/web/pdfs.html>  
<http://www.eere.energy.gov/communicationstandards/web/native.html>
- Be concise and get to the point. Break up content into chunks that are both easy to find and easy to read. Web site users have less patience than readers of hard copy, because reading from a screen is more difficult, and it's just so darned tempting to "click" away.

## **Be Appropriate**

- Use audience-appropriate language. At least one of your target audiences is made up of average consumers. Make content friendly to average folks; they don't understand architect or engineer speak. Avoid highly technical language. Define terms where necessary. Avoid jargon always.
- Obviously, profane, derogatory, or otherwise insulting language is not appropriate.
- Avoid critical and negative language.
- Choose graphics carefully. Use the right graphic files (.jpg files for photos, .gif files for graphics, especially if the graphic contains text). Be sure to constrain the proportions of an image when it is resized. Don't rely on the HTML image size tag to determine the size of an image. The image size should be set in a photo-editing program.

## **Build in Added Attractions**

- Make it personal; maybe even use a little humor. Let the user know that your team is made up of real people. Intersperse photographs of the team doing stuff. Add entertaining captions. But use good taste and don't denigrate your project by giving it an unappealing nickname or by alluding to inside jokes.
- Add some interactivity. How about a quiz with instant feedback to the reader? Or an energy-saver calculator? But don't make interactivity too complicated—keep the number of clicks and load times to a minimum.
- Include links to other Web sites, if those other sites contain really appropriate material. Links can sometimes make your Web site fare better in search engines too. Be careful: the danger here is that the reader may find the other Web sites more interesting than yours and never come back.

## Test for Usability

- Testing your Web site on people who represent your target users is invaluable to creating an effective site.
- When to test? Early! The earlier you test, the easier it is to make changes.
- Who to test?
  - o Not your team members!
  - o Family, friends, sponsors, students and faculty, representatives from your school's media relations office. Testers should have at least average computer and Internet experience.
- What to test?
  - o Ease and efficiency of use—can the users find the information they're looking for easily? With a minimal number of clicks? Is it easy to return to a previous page or to get to other pages on the site?
- How to test? Here's one inexpensive way:
  - o Paper Prototypes
    - Hand sketches
    - Photocopies, print outs, or screenshots of early design concepts
    - Hardcopies or electronic files of content or content outline
    - Combination of any of the above.
  - o Why Paper Prototypes?
    - Uses minimal resources
    - Easy way to try out multiple ideas
    - Facilitates buy-in: If you choose testers who are also sponsors, and people who want to follow the competition—people who will actually use the site—they will feel like they're going to make a difference, and they will feel more excited about being part of the project.
    - Validation—you know the design, architecture, and content work.
  - o What can be evaluated?
    - Information architecture (content organization)
    - Navigation
    - Naming, layout, groupings, and design of navigation elements
    - Content
    - Terminology and language
    - Get help from experts.

- Recruit a student who is an experienced Web producer or who is studying Web design and development. Ask that person to assume ownership of the Web site.
- Contact the English or Communications Department of your school and recruit a strong writer and copy editor onto your Solar Decathlon team. Web designers, producers, and developers are not typically content providers. Find a writer to do the writing. (Remember: Content is king.)
- Recruit a graphic designer onto your team—not all graphic designers can design for both Web and print; make sure you’ve got both areas covered.

## **Wrap it Up**

- Spell check programs are free, readily available, and easy to use. Run each Web page through a spell check.
- Spell check programs aren’t enough. Have a copy editor review the site for readability, spelling, and grammar.
- Systematically check all navigation and other links—this is an essential and painstaking process, even mind numbing, but it has to be done.
- Finally, when you finish creating your Web site, find someone who has never seen it before and whose judgment you trust. Ask him or her to read through your Web site. You’ll be surprised at the errors that person will find.

## **Ongoing Maintenance**

- Update content as frequently as is appropriate.
- Change the photos.
- Regularly check all links to ensure they are still functioning.
- Make sure the "Last Updated" message changes appropriately.
- Spell check, copy edit, and check all new links when you update the site.

## **Additional Resources**

Accessibility: <http://webaim.org/>

Award-winning Web sites, Webby Awards: <http://www.webbyawards.com/>

User Interface Engineering: <http://www.uie.com/>

### *Print Publications*

SAMS Teach Yourself Web Publishing with HTML & XHTML, Laura Lemay, Rafe Colburn. 2003.

JavaScript: The Definitive Guide, David Flanagan. 2001.

Cascading Style Sheets: The Definitive Guide (2<sup>nd</sup> edition), Eric A. Meyer. 2004.

Information Architecture for the World Wide Web (2<sup>nd</sup> edition), Louis Rosenfeld, Peter Morville. 2002.

## Instructions for Submitting Images

To ensure that the Organizers can use your images most effectively, we ask that you follow these instructions. You must include the information we will need when you submit files, or we will not credit the image. All images may be made available to the general public via the U.S. Department of Energy, the National Renewable Energy Laboratory, and the Solar Decathlon sponsor Web sites with unrestricted use. Images and any publications in which the images appear will be viewable without restrictions on the Internet.

### Submittal Requirements:

- Format: Electronic files (TIFF or JPEG [.jpg])
- Size: 8 in. by 10 in. (or closest metric equivalent), minimum
- Resolution: 300 dpi (or closest metric equivalent), minimum.

### Information we will need:

- Name, phone number, and e-mail of person submitting image
- Image description
- If image is a photograph:
  - Date photograph was taken
  - Place photograph was taken
  - Photographer's name and affiliation
- If image is a graphic:
  - Name of person or organization to credit

### How to send us your images:

- Solar Decathlon ftp site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/](ftp://ftp.nrel.gov/pub/solar_decathlon/)). Drop image files into the folder "submit\_images." You will not be able to see that your file has been successfully transferred. Please notify the specific requestor of the image files when the file has been transferred, and he or she will ensure that the transfer was successful. Include the information we will need in your notification.

- E-mail to a specific requestor. Ask the requestor for an e-mail address. Include the information we need in your email.
- Image files on disc or CD. Mail to a specific requestor at NREL. Ask the requestor for a mailing address. Include the information we will need in a cover letter.

# **Instrumentation and Monitoring: Design Considerations for Teams**

## **Introduction**

Measurements of temperature, humidity, electric power, and illuminance determine a significant portion of the Solar Decathlon scores. This document describes what the Organizers will install in teams' houses and how teams can help facilitate this work.

The location of sensors is determined via a negotiation between each Solar Decathlon team and the Organizers. The Organizers negotiate in good faith and try to achieve an equitable outcome for all teams. There is significant flexibility regarding location and wiring details. The negotiations will start well before the Event, but some details may be worked out at the last minute. Teams are welcome to propose specific locations as their house designs progress. Teams may also ask the Organizers for recommendations. The Organizers will start making proposals for sensor locations soon after they review the teams' Drawings and Specifications.

Accommodating instrumentation is not directly part of the scoring. However, sensors must be installed or teams can't get a score in the performance-based Contest Activities. Consequently, the Organizers suggest that teams accommodate the sensors sooner rather than later.

In the following sections, the primary components of the monitoring system are described.

## **Datalogger**

The datalogger box is 14 in. (36 cm) wide, 16 in. (41 cm) high, and 8 in. (20 cm) deep. It weighs about 12 lb (5 kg). The door hinge is on the left when facing the box. The Organizers are currently planning to use wired (as opposed to wireless) sensors, so a route must be provided for running sensor wires from each sensor location to the datalogger. Wires from sensors are usually inserted through the conduit bushing in the bottom of the datalogger box. These wires are usually not installed in conduit. The datalogger box is usually mounted in a vertical orientation using screws to attach it to a wall surface at a height above the floor that provides convenient working access. The typical location for the datalogger box is in a utility room or closet. The box can be mounted horizontally or upside down if the normal orientation is not available. The datalogger requires a small amount of electric power (approximately 2 watts) from the house's electric system, with the burden on each house being the same. A standard 120 VAC receptacle is usually used to supply this power. The Organizers communicate with the datalogger via a wireless modem located inside or adjacent to the datalogger box. An external antenna may be required for successful wireless modem communication. However, in the past, no external antennas were required.

## **Main Battery Shunt**

The scoring for Contest 9: Energy Balance requires measurement of the DC electric energy flow into and out of the battery bank. The Organizers plan to use a shunt to measure current and a voltage divider to measure the battery voltage. The installation of the main battery shunt can be time consuming because the battery cables are large and inflexible and there is typically limited space available to make the



connections. Many commercially fabricated DC load centers are available with a shunt already installed. If a team's DC panel already has a shunt, the Organizers will want to share the output signal from the shunt. If the team's panel does not have a shunt, the Organizers will send one so it can be installed as the system is being built.

The Organizers need a route to run wires from the shunt and voltage divider to the datalogger. The DC load center is frequently located in the same utility space as the datalogger, so surface mounting of sensor wires is usually straightforward and appropriate.

This description of the Energy Balance monitoring approach applies to the case in which a team has only one battery bank. If a team's design includes more than one battery bank, the Organizers will duplicate the measurements for each battery bank. However, to avoid placing an excessive burden on the Organizers installing instrumentation, systems should have just one main battery bank. If a team is proposing to use more than one battery bank, it must provide justification and that justification must be approved by the Organizers.

## **Light Sensors**

Contest 8: Lighting requires that a minimum average lighting level be maintained on the workstation desk surface during certain hours. The Organizers will install a photometer on the desk to continuously measure the illuminance on the horizontal work surface. The photometer with its base is about 3 in. (8 cm) in diameter and about 1 in. (3 cm) high and requires a wire to connect it to the datalogger. The Organizers will negotiate with each team to determine a specific location that is representative of the task lighting and accommodates other normal activities on the desk.

## **Temperature and Relative Humidity Sensors**

The scoring in Contest 5: Comfort Zone is derived from the measured dry bulb temperature and relative humidity inside the house. The Organizers plan to use a temperature and relative humidity sensor mounted inside a radiation shield to make this measurement. The sensor will be placed in a location that is representative of the temperature and humidity conditions through the entire house. This location will usually be between 4 and 5 ft (1 and 2 m) above the floor in the largest open room of the house. A location adjacent to a standard house thermostat is typical. In a closed bedroom, on an exterior wall, near the floor or ceiling, or near a window are all highly undesirable locations. If there is clearly more than one zone in the house, the Organizers will install more than one sensor. In this case, the measured temperature farthest from the target range will be counted. The objective of Contest 5 is to heat and cool the house (not to heat and cool the temperature sensor) and to maintain comfort conditions throughout the entire space.

The temperatures inside the refrigerator and freezer will be measured with thermocouples. These measurements typically require the placement of a small wire through the refrigerator or freezer door so that the gasket closes around the wire. This approach was used in the past with satisfactory results. The Organizers will identify a route for the thermocouple wires to be run from the datalogger to the refrigerator and freezer. If a team is concerned that jamming wires in the door will significantly impair the thermal performance, note that all teams are subject to the same installation approach. If a team is going to use a nonstandard door gasket, the Organizers need to be made aware of it.

### **Extended Monitoring Opportunity (Optional)**

The Organizers are interested in conducting extended performance monitoring of a limited number of well-performing houses after the houses have been reassembled on permanent sites after the Competition. Teams interested in participating in these monitoring activities are encouraged to accommodate future instrumentation in the current design. Detailed information about this monitoring opportunity will be posted on the Yahoo! Group for interested teams.

# Subjective Contest Activity Guidelines for Juries and Teams

## *Guidelines for Juries*

1. Teams have been given the option of preparing [brief contest reports](#) for many of the subjective Contest Activities. Reports will be made available to the Architecture, Engineering, Market Appeal, Communications, and Lighting Juries. Before arriving on the Mall to perform evaluations, please review the reports submitted by the teams to gain some familiarity with each team's efforts in the particular area being evaluated. The reports should make the judging process at the Event more efficient. If questions arise in the review of the contest reports, you may discuss those questions with the appropriate Contest Official at the Event.
2. Place each team into one of four classes. See below for the range of percentage integers associated with each class. Contest Activity criteria are included in each Contest Activity description.

Class #1: ECLIPSES Contest Activity criteria	91 – 100% of available points
Class #2: EXCEEDS Contest Activity criteria	81 – 90% of available points
Class #3: EQUALS Contest Activity criteria	61 – 80% of available points
Class #4: APPROACHES Contest Activity criteria	0 – 60% of available points

You are not required to place a uniform number of teams in all classes or to place at least one team in every class. For example, if you determine that no teams are worthy of class #1, there would be no teams with scores greater than 90%. Note that the placing of teams into classes (as a first step toward assigning an eventual percentage integer) is encouraged to ease the process of evaluating so many teams at one time.

3. After all the teams have been placed into a class, Jurors should assign each team a specific percentage integer from 0% to 100% according to ranges established for the appropriate scoring classes. If it is possible to further separate teams within a particular class, assigning different percentages within the allowed range of the particular class is encouraged. The assigned percentage may fall anywhere within the range associated with the class. If it is not possible to further separate teams within a particular class, it may be appropriate to assign each team in a particular class the same percentage.
4. Discuss your evaluation of each team as a Jury—as a whole group—until a consensus percentage is reached for each team.

5. After assigning each team a percentage integer, the percentages should be submitted to the Contest Official. The Contest Official will then give the percentages to the Scorekeeper, who will convert them into an actual score based on the total number of available points for the Contest Activity being judged. Prior to posting points, the Scoring Official will apply any applicable penalties that may have been incurred.
6. Submit a brief summary of scoring justifications for each team to the Contest Official. A summary of the Jury's justifications will be provided as feedback to each team so it might better understand why the Jury evaluated the team as it did.

## ***Guidance for Teams***

1. Show the Architecture, Engineering, Market Appeal, and Lighting Juries all possible configurations of the house during their tours. (Teams are not required to show all configurations of the house to the Communications Jury.) House configurations that could affect the outcome of contests and that were not seen by the Jury during their tours are prohibited during Contest Week.

Three examples of reconfigurable features follow:

- A significant moveable component, such as a room, wall, or bed (safety plan must also be in place)
- Significant shading devices, such as retractable awnings or operable shutters
- Window coverings that may reduce light levels.

If you do not have time to do a live reconfiguration during the Jury tours, you must use some other method, such as photographs or video, to show all reconfigurable features in their various configurations. If you are not planning to actually reconfigure qualifying features at any time during Contest Week, you do not have to show the reconfiguration to the Juries.

2. The Organizers will provide all Juries with summaries of important Rules and Regulations and code violations for each team so that Juries are aware of violations before giving credit for aspects of the project that are not in compliance.
3. Up to six (6) Decathletes, i.e., student Team Members, may give tours to the Juries. Faculty, contractors, and volunteers may not give tours to the Juries. However, a faculty member may be a silent observer during the Jury tours.
4. Teams may offer handouts prepared for public distribution to the members of the Juries (refer to [Section 3.2.2](#) in the Solar Decathlon Building Code). The Brief Contest Reports are the only materials to be made available to the Jurors that address specific topics of particular interest to each individual Jury. However, presentation boards expanding on the topics summarized in the Brief Contest Reports are permitted to be on display during Jury tours.

5. One of the six participating Decathletes can audiotape or videotape the Jury Tours as they are happening, but taping of the Jury deliberations is prohibited.
6. Areas of the house not located on the accessible route may be accessed by the Juries and considered in their evaluations.

## Food Safety Guidelines

Teams are required to submit detailed dinner party menus to the Organizers in accordance with these rules. One electronic copy (Microsoft Word document or Adobe PDF) of the menu must be uploaded to the appropriate team folder on the Solar Decathlon FTP site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/Team\\_Folders/](ftp://ftp.nrel.gov/pub/solar_decathlon/Team_Folders/)) or submitted to Mike Wassmer at [michael\\_wassmer@nrel.gov](mailto:michael_wassmer@nrel.gov) on or before August 7, 2007. To be considered “on time,” meal plans must arrive at their intended destination by 5 p.m. (mountain time) on the due date. The Organizers will review the meal plans for compliance.

The following safety requirements must be met to participate in the Dinner Party Contest Activity.

- To comply with National Park Service rules, no food may be served to the general public.
- No alcoholic beverages may be stored, used in meal preparation, served, or used in a meal in any way.
- No raw eggs, raw meats, or raw fish may be stored, prepared, served, or used in a meal in any way.
- All water used for cooking and drinking shall be drinking water purchased in sealed containers. The use of the house’s main water supply system is not permitted for these applications.
- If the requirements of the dishwashing tasks for [Contest 6: Appliances](#) are not met, meals must be prepared and served using equipment (e.g., cups, glasses, plates, utensils, and pots and pans) that has been sterilized or that is disposable.
- Normal domestic wastewater may go into the wastewater tank. Hazardous or toxic chemicals are not allowed in the wastewater tank.
- All frozen beverages and foods must be stored in the freezer until preparation for serving.
- All beverages and food must be stored properly and according to the instructions on the packaging. For example, beverages and foods marked “refrigerate after opening” must be refrigerated appropriately after opening.
- Precooked, prepackaged, factory-sealed items (e.g., canned, frozen, and prepackaged, precooked, factory-sealed meats) are allowed provided they are stored and prepared according to the guidelines at the Center for Food Safety and Applied Nutrition (CFSAN) and the Food and Drug Administration’s (FDA) Web site at <http://www.cfsan.fda.gov/~dms/fttcook.html>. Take-out and over-the-counter delicatessen food items will not be permitted because they are not prepackaged and factory-sealed.
- When planning meals, please consider that the people you will be feeding might have food allergies. Common food allergies are: milk/dairy products, eggs, peanuts, tree nuts (walnut, cashew, pecans, etc.), fish, shellfish, soy, and wheat. To help prevent allergic reaction, the Organizers recommend that the teams create a list of ingredients for each of the items being served at each meal.

## Project Summary Requirements

The material requested in these project summaries is important. It helps the Organizers stay in touch with the teams. It helps the Organizers respond efficiently to media inquiries. It provides potential sponsors with information. It provides important content for the communications materials (e.g., the Web site and Competition program) that the Organizers are developing in preparation for the Event. And, it will become part of the content in the final report, produced by the Organizers after the Event, about the 2007 Solar Decathlon.

This material is also important to the teams. The teams can earn points in Contest 3: Market Viability by submitting these summaries. It can be used to develop content for Web sites and house tours for Contest 4: Communications. It will help teams develop materials to find sponsors. It will help with any reporting requirements a team's school or sponsors might have. It mimics the kind of reporting many team members will have to do in their professional careers. And, it will prepare teams to answer the kinds of questions that visitors to their construction sites and to the Event on the Mall are sure to have.

The deadlines for project summary submissions are June 13, 2006; March 6, 2007; August 7, 2007; and January 9, 2008. One electronic copy (Microsoft Word document or Adobe PDF) of each summary must be uploaded to the appropriate team folder on the Solar Decathlon FTP site ([ftp://ftp.nrel.gov/pub/solar\\_decathlon/Team\\_Folders/](ftp://ftp.nrel.gov/pub/solar_decathlon/Team_Folders/)) or submitted to Mike Wassmer at [michael\\_wassmer@nrel.gov](mailto:michael_wassmer@nrel.gov) on or before the respective deadlines. To be considered "on time," project summaries must arrive at their intended destination by 5 p.m. (Mountain time) on the due date. Each project summary should include, but is not limited to, the following items.

### Team Information

- Team photograph: indicate names and titles of the people in the photo and follow the [Instructions for Submitting Images](#). If there has been no change in team members from one submission of a project summary to the next, there is no need to submit another photo.
- Team organization and contacts: The Organizers want to know how each team is organized and approximately how many students, faculty, and others (e.g., sponsors, volunteers, family members) are involved in each Project. The teams should provide contact information (name, title and/or Project title, mailing address, e-mail address, and phone and fax numbers) for as many team members in leadership positions as possible (at a minimum, Faculty Advisor, student team leader, communications contact, media relations contact, house transportation contact, building inspection contact, fire watch captain, and safety officer). Even if contact information doesn't change between submissions of project summaries, please resubmit this information.

## Narrative

- The narrative is the story of the Project to date, in narrative form (3 to 5 pages [no more than 5 pages], 11 pt. type, double spaced, 1-in. (or metric equivalent) margins). Projects are works-in-progress; after the first project narrative submission, teams should provide new information or update previous information. Do not repeat previous information.
- Team mission statement, goals, and values: What is the team's "personality?" What does the team want to accomplish? What does the team care about? What has changed and why?
- Discussion of design philosophy and house design: What is the point of the design? What is the team trying to say or trying to accomplish with this design? What will the house look like? What are some of the key features? Why is the team making the choices it's making? What makes the house stand out, or appear unique? How will the need for portability affect the design? What has changed and why?
- Characterize the team's accomplishments and planning: What did the team plan to do and why? What has it succeeded in doing and how? What has the team done that wasn't planned for and why? What are the team's future plans? What has changed and why?
- Teams are free to include images, but must follow [Instructions for Submitting Images](#).



# Battery Requirements and Guidelines

## Introduction

This supplemental document identifies and discusses codes, regulations, and best practices for battery use and installation as they relate to the Solar Decathlon. A battery system can be hazardous because it is a continuously “energized” source of electricity and contains corrosive electrolytes. Also, batteries can be heavy, can cause fires, and can produce explosive or corrosive gases. Solar Decathlon team members need to be aware of these inherent hazards to minimize the risk to themselves and the public when transporting, installing, maintaining, using, or replacing a battery. Although this document focuses on lead-acid batteries, most of the information and discussion applies to all battery chemistries.

Because this competition has a strong public outreach component, the Organizers are providing these guidelines to reinforce the importance of safety at the Event. The public viewing the Solar Decathlon homes may choose to incorporate some of the features and technologies in their own homes. Because solar-powered homes will be new to many people, the homes need to demonstrate safe photovoltaic (PV) and battery systems. Although most people are familiar with automotive batteries, the batteries in the Solar Decathlon homes will be larger, and they are subject to additional regulations and considerations.

## *General Applicability and Interpretation*

This document lists and discusses most of the codes, standards, and recommendations that apply to batteries typically used in solar-powered homes. Although the list may look exhaustive, some codes, standards, or recommendations have been left out intentionally or may have been left out inadvertently. Also, state and local jurisdictions and the sponsoring school may have additional requirements beyond the international or national codes listed here.

Interpreting the codes, regulations, and recommendations is ultimately the responsibility of the individual Solar Decathlon teams and their institutions. In this document, the Organizers have established a minimum level of battery safety consistent with published codes, regulations, and recommendations. Individual teams or their sponsoring institution may add their own additional requirements.

Battery codes, regulations, and recommendations have only a minor impact on the home’s energy usage. Batteries are emphasized here primarily because they represent an important safety issue. Teams must make safety a priority throughout the competition.

In addition to safety, proper interpretation of codes, regulations, and recommendations can improve a battery’s performance and extend its lifetime. Although the Solar Decathlon competition on the National Mall takes place over a brief period of time, a battery system should be designed, installed, and operated as if the house were to be occupied full time and the battery system lifetime needed to be maximized

through proper operation and maintenance. The public will scrutinize the Solar Decathlon homes and the schools they represent, so all battery systems must be properly installed and operated.

### ***Battery Terminology***

Commonly accepted terms will be defined to interpret the codes and to discuss the issues within the context of the Solar Decathlon Rules and Regulations and with other battery industry experts. The **cell** is the smallest electrical unit capable of producing voltage. In the lead-acid battery chemistry, the cell produces 2 V nominally. The **battery** consists of ALL the cells that are series or parallel connected.

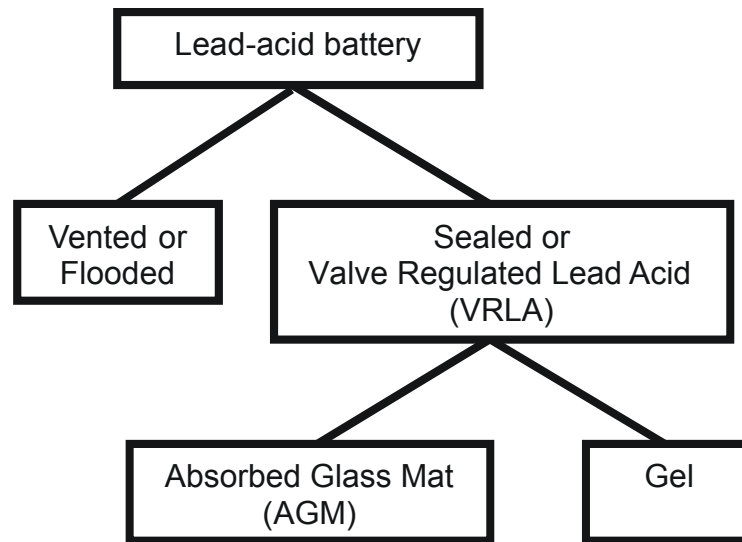
Confusion begins when referring to the home's battery. Many of the codes and standards refer to "batteries" as the collection of individual batteries that compose a battery. This publication, when discussing the Solar Decathlon competition, regulations, and suggested best practices, will refer to the house battery as the **battery bank** or **battery system**.

**State-of-charge (SOC)** is the percent of electrical energy stored in a battery compared to the manufacturer's rated capacity of the battery. A full battery has a 100% SOC and a discharged lead-acid battery has a 20% SOC. Most batteries are not fully discharged to 0% SOC, even though the manufacturer's rated capacity is based on a full discharge. **Depth-of-discharge (DOD)** is the inverse of SOC. A fully charged battery has a 0% DOD whereas a discharged lead-acid battery has an 80% DOD.

### ***Battery Chemistries***

There are several electrochemical battery types available for solar-powered homes. The most common battery type is lead-acid because of availability and cost. Other battery types that have been used are nickel-cadmium (NiCd), nickel-iron (NiFe), nickel metal hydride (NiMH) and lithium-ion. Each battery type has its own specific operating, transportation, cleanup, and disposal requirements. The battery manufacturer should supply this information along with a Material Safety Data Sheet (MSDS). Whereas some of the discussion in this document focuses on lead-acid batteries, most of the discussion is applicable to all types of batteries.

Most of the battery chemistries can be incorporated into vented or sealed battery configurations. Figure 1 shows the different types of lead-acid batteries. The vented (or flooded) configuration contains liquid electrolyte (either acid or base). During normal operation, electrolyte or electrolyte film may be present on top of the battery case because of the venting of hydrogen gas, overcharging, or overfilling vented configuration batteries. Standard maintenance requirements for a vented battery include visually checking the electrolyte level and adding distilled water, if needed. In the vented configuration, electrolyte can spill out if the battery is tipped, or if the case becomes damaged. A vented battery should come with spark arrestor vent caps for each cell. After-market hydrogen recombinant and spark arrestor vent caps may also be available to help reduce water loss. Check with the battery manufacturer before replacing any vent caps.



**Figure 1. Different types of lead-acid batteries**

The sealed (or valve-regulated lead-acid [VRLA]) battery configuration avoids many of the vented battery configuration's disadvantages by immobilizing or minimizing the electrolyte. Absorbed glass mat (AGM) batteries are different than gel batteries, even though both are sealed lead-acid batteries. An AGM battery immobilizes the electrolyte by absorbing the electrolyte into a fiberglass mat. A gel battery immobilizes the electrolyte by adding silica gel, creating a semi-solid mass.

Under normal operating conditions in a sealed battery, the hydrogen gas that is generated during charging and discharging is recombined with oxygen inside the cell. Depending on the manufacturer, sealed batteries can usually be placed in any orientation (with the battery terminals on top or on the side). Some manufacturers claim that certain orientations of their sealed battery improve battery-recharging efficiency. Check with the manufacturer before placing a battery in an orientation different than as received. Sealed batteries are generally more convenient to install and operate, even though the initial and operating costs may be higher.

### ***Battery Hazards and Risks***

A battery presents many hazards and risks—all of which can be minimized through proper design, installation, operation, maintenance, and disposal. A battery is always “energized”—there is no on/off switch. Even a battery that is “discharged” still contains a lot of energy.

The corrosive electrolyte inside the battery can cause physical injuries to the user or additional damage to the battery if the electrolyte leaks out of the case, spills from the battery in an accident, or vents to the atmosphere. A battery can be heavy and awkward. Poorly designed battery rooms with limited space can hinder safe lifting and installation (or removal) of a battery. If improperly manufactured or maintained, a battery can cause a fire. Also, a fire near the battery can be started if the wiring and connections are improper or maintained poorly.

A vented or flooded battery will produce hydrogen gas during normal operation. A vented lead-acid battery with antimony-containing lead plates will produce more hydrogen than a battery with calcium-containing lead plates. A sealed or VRLA battery should contain all gases during normal operations. However, during abnormal circumstances, excess pressure inside the sealed battery will cause the battery to vent hydrogen gas. A sealed battery contains a one-way pressure relief vent that can release excess pressure from inside the battery case if the battery is overcharged or overheated, or if there is a battery failure. The total amount of hydrogen gas that can be generated from a vented or sealed battery can be similar, but depends on the total amount of electrolyte inside the battery. The rate of hydrogen evolution is a function of the SOC, battery age, and current.

In summary, the risks to be considered when installing, utilizing, and maintaining a battery bank are:

- Explosion/flammability of hydrogen gas
- Electric shock and electric current hazards
- Acidic or caustic electrolyte spills, exposure, or both
- Gravity related issues (such as battery lifting and batteries falling off racks due to seismic events).

## **Codes and Regulations**

There are several national level code organizations that regulate the use of battery systems in building applications. The codes and regulations cited here come from the National Fire Protection Association (NFPA), International Code Council (ICC), Occupational Safety & Health Administration (OSHA), and Department of Transportation (DOT).

## **Battery System Codes**

<b>Code Name</b>	<b>Relevant Section(s)</b>	<b>Location</b>	<b>Comments</b>
2005 National Electric Code (NEC)	Article 480 and Part VIII of Article 690	2005 NEC Handbook CD	Requirements for storage batteries and batteries used in PV installations
2006 International Fire Code (IFC)	Sections 608 and 609	2006 ICC Codes CD	Specific requirements for stationary lead-acid battery systems and VLRA battery systems
2006 International Mechanical Code (IMC)	Sections 502.1, 502.3, 502.4, 502.5	2006 ICC Codes CD	Ventilation requirements
OSHA Regulations	29 CFR Part 1926.441	<a href="http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&amp;p_id=10742">http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&amp;p_id=10742</a>	Not as detailed as other codes

## **Battery Shipping Regulations**

DOT classifies all electrochemical batteries as hazardous materials subject to regulation when transported in interstate commerce. Individual states generally adopt DOT regulations for intrastate commerce. All trucking companies and drivers should be familiar with the appropriate regulations for each state. Teams need to fully disclose to the driver and trucking company all potentially hazardous materials (batteries, ethylene-glycol, cleaning solvents, paints, etc.) that are being transported.

Most of the DOT regulations relevant to the Solar Decathlon are contained in Title 49 of the Federal Code of Regulations (49 CFR). The Hazardous Materials Table in 49 CFR Part 172.101 lists different types of batteries. All lead-acid batteries, both vented (flooded) and sealed (VRLA), are considered “wet batteries.” Section 49 CFR Part 173.159 describes wet batteries and their packaging requirements. Generally, loads with wet batteries need to be placarded (the diamond-shaped warning label on trucks), which requires a driver with a Commercial Drivers License (CDL) and a Hazardous Material endorsement. There are two possible placarding exceptions mentioned below.

49 CFR Part 173.159 (d) defines “nonspillable” batteries that do not require a placard if all requirements in that subsection are met. The battery manufacturer can state compliance with (d)(2) – labeling and (d)(3) – the vibration and pressure differential tests. Get a copy of the certification from the battery manufacturer. Subsection (d)(1) states, “The battery must be protected against short circuits and securely packaged.”

49 CFR Part 173.159 (e) could exempt flooded batteries from placarding if all four requirements are met. Subsection (e)(2) states, “The batteries must be loaded or braced so as to prevent damage and short circuits in transit.” Subsection (e)(3) states, “Any other material loaded in the same vehicle must be blocked, braced, or otherwise secured to prevent contact with or damage to the batteries.”

Compliance with the protecting, blocking, bracing, and preventing damage exceptions (d)(1), (e)(2), and (e)(3) in 49 CFR Part 173.159 is usually determined only after an accident. DOT inspectors will rarely give approval in advance. If there was an accident and the batteries shifted, broke, or caused a fire, the requirements probably weren’t met. The problem can cascade further. Because the exception wasn’t met, the truck should have been placarded and driven by a driver with a CDL and a Hazardous Material endorsement.

Because the Solar Decathlon homes will have a battery system and will be transported in interstate commerce, all DOT regulations are applicable. If a team hires a company to transport its home, the team must fully inform the company and driver about the weight and type of batteries and provide an MSDS. The transportation company assumes responsibility for compliance with all shipping regulations. If the team transports the home containing a battery system using its own driver, the driver (and possibly the school) assumes responsibility for meeting all DOT regulations.

Because of dynamic loading, a battery rack suitable for a stationary application will not be suitable for transportation. Teams should take special care in packing batteries for transportation. The battery system could be transported separately (from the house) and installed on site before the competition. After the competition, the battery system should be removed from the house for return transportation.

## Recommended or Best Practice Standards

The Institute of Electrical and Electronics Engineers (IEEE) publishes consensus standards on a wide variety of topics. An IEEE standard is useful because it presents best practice recommendations and reflects a consensus within the industry.

IEEE Standard	Title
450-1995	Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications
484-1996	Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications
485-1997	Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
928-1986	Recommended Criteria for Terrestrial PV Power Systems
929-2000	Recommended Practice for Utility Interface of PV Systems
937-2000	Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for PV Systems
1013-2000	Recommended Practice for Sizing Lead-Acid Batteries for PV Systems
1106-1995	Recommended Practice for Maintenance, Testing, and Replacement of Vented NiCd Batteries for Stationary Applications
1115-2000	Recommended Practice for Sizing NiCd Batteries for Stationary Applications
1145-1999	Recommended Practice for Installation and Maintenance of NiCd Batteries for PV Systems
1187-1996	Recommended Practice for Installation Design and Installation of VRLA Batteries for Stationary Applications
1188-1996	Recommended Practice for Maintenance, Testing, and Replacement of VRLA Batteries for Stationary Applications
1189-1996	Guide for Selection of VRLA Batteries for Stationary Applications
1374-1998	Guide for Terrestrial Photovoltaic Power System Safety
1375-1998	Guide for Protection of Stationary Battery Systems

IEEE standards written specifically for PV systems with a battery system are 928, 937, 1013, 1145, and 1374. The other standards may contain additional information that is useful for design and installation of any battery. IEEE Standard 929 is appropriate for grid-connected, utility-interactive PV systems.

## **Solar Decathlon Competition**

### ***National Park Service Requirements***

National Park Service (NPS) is asking decathlon teams to adhere to OSHA standards.

### ***Inspections***

As with all codes, ultimately the code inspectors will determine if the code is met physically or by intent. Appropriate calculations for seismic design of racks and ventilation requirements for battery systems should be submitted for approval in advance. Onsite inspections before the competition will be performed to ensure that health and safety requirements are met.

### ***Performance Monitoring Requirements***

Organizers expect teams to have a single physical location where the battery bank may be monitored with a watt transducer, shunt, or similar device. All electrical layouts that have separate PV arrays serving separate battery banks are discouraged and must be approved by the Rules and Regulations Committee.

### **Discussion, Best Practices, and Suggestions**

Although not directly related to a Solar Decathlon Contest, battery system operation and maintenance, battery system locations, ventilation, enclosures, secondary containment, racks, and proper protective apparel can affect overall safety and can impact the cost of your renewable energy system over its lifetime. To help teams meet code requirements, the following provides suggestions and outlines best practices when designing, installing, maintaining, and utilizing a battery system.

### ***Battery Operation and Maintenance Considerations***

Something as mundane and easy to forget as battery maintenance can make or break the economics of your system. Pay careful attention to battery manufacturer recommendations, in terms of maintenance, to get the most out of your battery system.

The battery is the most significant element in your renewable energy power system that has variable efficiency. Depending on how well you take care of your batteries, you can realize round trip and life efficiencies that vary from as low as 20%–30% to as high as 85%–90%. Choosing the right charge/discharge strategy; selecting the correct battery system charger/charge controller; and utilizing a sound dispatch strategy for charging devices, meeting loads and auxiliary loads are all important.



## Operation

The renewable energy system designer/operator can control battery system operation to a large degree. How the designer/operator manages the battery system will have a strong effect on how well the battery system performs and how long it lasts. Proper management can also minimize safety risks.

Sometimes, it is difficult to find literature (from manufacturers, testing agencies, and academia alike) that describes exactly how to get the most out of a bank of batteries. Required parameters such as load profile, type of charging sources, resource profiles, dispatch strategy, dump load dispatch, etc., can vary from system to system. Therefore, this variability makes it difficult to understand each system well enough to optimize its battery operation strategy. There are, however, a few guidelines to keep in mind when developing your own operation strategy for your specific renewable energy system. They include the following.

1. Batteries reach peak round trip efficiencies when operated in the 50%–85% SOC range.
2. Batteries cannot stay too long in the 75%–90% SOC range without damage from sulfation (i.e., batteries need to be periodically fully charged, on a monthly or a quarterly basis).
3. Batteries kept at a high SOC (such as float or standby) can last a very long time. However, they will not realize much throughput in their lifetime.
4. Batteries repeatedly deeply discharged (to as low as 20% SOC) will realize a higher throughput but a shorter life (some manufacturers recommend discharging to 50% SOC to extend the battery life).
5. Manufacturers can or will often provide a curve that describes the depth of discharge/cycle life relationship. However, these curves are produced under fairly strict conditions that can be difficult to duplicate in the field. Treat these curves as a reference, not a warranty.
6. When there is a large amount of sunlight, it's probably better to run as many productive loads (e.g., pump water, chill milk, and make ice) as you can to reduce the amount of energy that needs to be cycled through your battery system.
7. Avoid leaving batteries at a low SOC because batteries left at a low SOC can begin to sulfate within days.

## Maintenance

A well maintained and operated battery system can last many years. A poorly maintained and operated battery system can last a matter of weeks. Clearly, it's easier to damage a battery system than it is to maintain it well. However, here is a list of checks that can be performed (most battery maintenance guides will include at least some of these checks).

#### Monthly:

1. Visually inspect the batteries (look for corrosion, damaged or missing caps, wet/damp spots around caps, cracks or leaks, signs of heaving posts, damaged cable leads, damaged terminals or connectors).
2. Physically check for loose connections (loose connections can lead to overheating and seriously affect battery efficiency).
3. Check the temperature at the battery terminal and look for batteries that deviate (thermally) from the norm.
4. Take voltages of each battery (or cell if using 2 V cells) with and without current flowing and look for variation from the average. The cell voltage for a battery at open circuit that shows variation of as little as 0.15 V from the average can indicate a problem with that battery.
5. If using vented (flooded) batteries, take specific gravity measurements with the batteries at open circuit and look for any variations from the mean (a variation of as little as 0.02 can indicate a problem with that battery).
6. Also, if using vented (flooded) batteries, check fluid levels and fill as required (never allow the plates to become exposed to the air, use only distilled water, note which batteries are using more water and see if a pattern is developing, don't overfill with water, and never remove excess electrolyte solution).
7. Clean the tops of the batteries with a solution of 1/8 lb. baking soda per quart of warm water. Check with the battery manufacturer for approved detergents.

#### Quarterly (in addition to the monthly checks):

1. Check connection resistance of inter-cell or inter-battery connectors (one step more than looking for loose connections) of 10% of the battery system.
2. Measure the temperature of a random sample of 20% of the battery system.

#### Annually (in addition to monthly and quarterly checks):

1. Tighten all bolts to recommended torque.
2. Record all connection resistances.
3. Perform a capacity test.

Optional: Thermographic scans (if this technology is available—even a camcorder with infrared imaging can do the trick) can provide an excellent insight into connection problems between batteries or cells.

If your system is equipped with a battery monitor (E-meter, Tri-Metric, Data Acquisition System [DAS], etc.), periodically check your round trip efficiencies. A drop in efficiency doesn't necessarily mean that your whole battery bank is dead. It is more likely that a few batteries or cells within the battery bank need to be replaced or charged separately. The sooner you replace or charge a battery or cell that is pulling an entire string down, the better. Battery banks tend to experience cascade-type failures. A single bad battery or cell may accept less current, causing the entire battery bank to accept less current.

These guidelines are only an example, and not an exemplary, maintenance guide. For a more comprehensive and thorough manual, contact the battery manufacturer; most battery manufacturers will provide a manual. Proper operation and maintenance does not guarantee that you will not experience some sort of failure in at least one of your batteries before the battery bank reaches its maximum expected life cycle. Yet, failure to maintain your battery bank all but guarantees a shortened and inefficient life for your batteries.

### ***Good Battery System Locations***

Sometimes the placement of a battery bank is an afterthought. This is not a good idea. As mentioned previously, proper operation and maintenance of your battery bank can make the difference in the economic viability of your renewable energy system. If a battery is not in an accessible location, proper maintenance probably will not happen, or if it does, it will be a nuisance every time it is done. Also, the environment surrounding the batteries (such as ambient temperature) can have a serious impact on the expected life of the batteries (overheating of batteries is one of the principal failure modes). Finally, the distance between the batteries and the principal load (typically the inverter) is directly related to system efficiency (the closer the two are, the better).

Accessibility to the battery system increases the likelihood of its proper maintenance in a safe manner. Storing batteries in a mechanical crawl space or in an attic exposes batteries to elevated temperatures. This is probably one of the fastest methods to ruin a battery bank. A battery bank should be placed in an enclosure with a locked cover, or in a separate room with a door that can be locked.

Keep in mind the following guidelines when planning where to place batteries.

- For vented (flooded) batteries, a minimum of 18 in. is required between the top of the battery or battery post (whichever is higher) and the structure above it, to allow safe inspection and routine maintenance. For sealed or VRLA batteries, a reasonable working distance is required.
- Minimize the distance between batteries and the primary load. (Not only does cable become expensive if batteries are placed far from the inverter, but the induction of cables becomes a factor.)
- Protect batteries from overheating and from cell-to-cell temperature variations. (Don't place them in an attic or mechanical space that experiences high temperatures. Don't place them in a dark box on the south side of the house. Don't put them above or too near a heat source.)

- Protect batteries from cold and freezing. Whereas a charged battery has a low freezing point, a cold battery has less available capacity.
- Make the battery system accessible for routine inspections and maintenance.
- Don't place batteries directly below electronics. Batteries can (and vented batteries do) emit corrosive gases that are damaging to many things, especially electronics.
- Don't locate batteries where things will be inadvertently dropped on them.

## **Ventilation**

Code references for this section:

- IMC2006: Sections 502.3, 502.4, and 502.5
- IFC2006: Sections 608.5, 609.6, and 609.7

Hydrogen gas presents a fire hazard in any battery system installation regardless of battery type. Abnormal conditions, such as failure of the charge controller, may cause the PV charging current to flow unregulated into a fully charged battery system. In some cases, an individual cell on the battery fails and will act as a sink for the full battery system current. If any type of battery is overcharged, it can emit significant amounts of hydrogen. The total volume could be less in some battery types because there is less electrolyte, but the maximum rate of gas evolution can be similar. For scenarios like these, Solar Decathlon regulations require a well-designed ventilation system.

Hydrogen gas is very light and has a strong propensity to disperse. It is also highly combustible and can ignite under a relatively wide range of conditions (batteries have been known to explode even in open air). Because vented or flooded batteries emit hydrogen gas, special care should be taken to avoid its accumulation. Sealed batteries certainly can, have, and do emit hydrogen gas when something goes wrong. Therefore, all systems must ventilate, either passively or actively, directly to the outside air.

Energy consumption from a mechanical ventilation fan is a small portion of a building's total energy consumption. One measure to reduce the amount of energy used by ventilation fans is to only turn the fans on during charging and discharging of the battery bank.

With either mechanical ventilation or natural ventilation systems, the ventilation system should be designed to prevent pressure differentials on or around the building from causing hydrogen gas to accumulate in the ventilation pipe, duct, or devices.

In choosing whether to use active or passive ventilation systems, consider the following guidelines.

**Passive Ventilation:**

This type of ventilation is acceptable if the battery system room or enclosure has an exterior wall or opens to the exterior of the building. For this type of ventilation to work, vents must be placed near the ceiling and near the floor.

**Active Ventilation:**

This type of ventilation is required if the battery system room or enclosure does not have an exterior wall or exterior access. Unless a DC brushless motor is used, the fan motor must be located in outside air and must push fresh air into the battery system room or enclosure. The ventilation fan should be activated when charging or discharging the battery system but must also be fail-safe. (A DC fan that runs directly from the batteries via a normally closed relay is an acceptable form of a fail-safe system. An AC fan that runs off the inverter is not).

## ***Enclosures***

Code references for this section: IFC2006 Sections 608.3, 608.7, 609.4, and 609.9

Battery systems must be fully contained in enclosures or rooms that remain within the 800-ft<sup>2</sup> footprint. A battery system room will be permitted in lieu of a separate battery system enclosure if designed in accordance with IFC2006 Section 608.3 or 609.4.

A battery system enclosure is an appropriate means of separating the batteries from the rest of the electrical equipment, without building a separate room. This protects electrical equipment from battery gas emissions, minimizes the volume required to be ventilated (especially important if the electrical/battery system room does not have an exterior wall or exterior access), and prevents accidental contact with the batteries. Battery system enclosures must be constructed of acid-resistant materials (most plastics). A plastic bag draped over the tops of the batteries is not an enclosure. Whether or not an enclosure is used, all batteries should have some means of preventing accidental contact across the terminals. (Plexiglas or rigid plastic covers are acceptable.) The cover must be locked so access to batteries inside the enclosure is limited to the team's decathletes.

For inspection and maintenance purposes, the top of an enclosure should be at least 18 in. above the top of a battery or battery post (whichever is higher) unless the lid of the enclosure is hinged. A hinged lid on the enclosure will allow adequate access for maintenance and inspection and therefore can be in closer proximity to the top of a battery or battery post. It is recommended that the lid not touch the post or an electrical conductor under any circumstance.

## ***Secondary Containment***

Code references for this section: IFC2006 Sections 608.4 and 609.5

The purpose of secondary containment is both to capture any spills from watering vented or flooded cells as well as to capture any leaks from cracked or damaged batteries. Secondary containment systems should be sized according to IFC2006 Section 608.4 so as to capture the entire contents of at least one battery. Secondary containment systems only work when constructed of sealed, acid-resistant material. A plastic bag is not considered secondary containment.

If racks are used, secondary containment should be used on each rack level. Whereas a single pan at the lowest level may protect the environment, it does not protect the lower batteries from what goes on above.

## ***Battery System Racks and Stacking***

Code references for this section:

- NEC2005 Section 480.8
- IFC2006 Sections 608.7 and 609.9

If possible, battery system racks should be designed such that batteries are easily inspected, cleaned, and maintained. Most racks will have two levels and under certain circumstances may have three levels. As stated before, accessibility increases likelihood of proper maintenance. Keeping rack height minimized offers better accessibility. It also diminishes the likelihood of injury due to lifting batteries. For example, lifting a battery above a person's head to place it on the rack could be a dangerous situation.

Battery racks can provide an appropriate means of assembling many batteries within a smaller footprint; but care needs to be taken in the selection and design of the battery system rack. The rack levels must be spaced so as to allow easy and safe access to each battery level during routine inspection and maintenance. For vented batteries, a minimum of 18 in. is required between the top of a battery or battery post (whichever is higher) and the rack structure or ceiling above. This amount of space is required for safe inspection and maintenance. All racks containing sealed batteries must provide adequate space for access with tools to verify tightness of terminal connections.

## ***Placement of Disconnects***

Code references for this section: NEC2005 Article 230 Part VI and Article 690 Part III

Battery system disconnects should be located as close to the exit as possible, should be as close to shoulder height as possible, and should be clearly labeled. Battery system disconnects, like fire extinguishers, should be readily accessible in case of an emergency. It should not be necessary to enter deep into a room where batteries are experiencing catastrophic failure to actuate the battery system disconnects. In addition, battery system disconnects should be readily accessible for emergency response personnel.

## ***Other Considerations***

Proper spill clean-up kits should be on hand in the event of electrolyte spills. Proper personal protective equipment (PPE) should be available for dealing with leaking cells and cleanup of electrolyte.

Smoke alarms should be placed in the electrical space where batteries are contained. The smoke alarm should be loud enough or should have a remote location indicator so the alarm can be heard outside of the electrical space. Fire extinguishers rated for electrical and chemical fires should be on hand in the event of battery failure.

In addition to any NEC requirements regarding the electrical system of the entire house, all battery enclosures shall be marked with the National Fire Protection Association's (NFPA) Hazard Warning Diamond appropriate to the battery technology contained within the enclosure.